PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON

USDA/STATE/EPA ASSESSMENT TEAM OF THE
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This report was prepared jointly by the U.S. Environmental Protection Agency, the U.S. Department of Agriculture and Cooperating State Agencies. It represents the cumulative efforts of many individuals from these agencies. The principal contributors were members of the USDA/State/EPA Diflubenzuron Assessment Team, established pursuant to a Memorandum of Understanding between USDA and EPA. Richard L. Ridgway served as Team Leader for this Assessment Team.

It is almost impossible to assign authorship to various sections of a report of this nature due to the wide participation of so many individuals in so many phases of the report. Nonetheless, an attempt has been made to identify principal authors wherever possible. This identification will be found on each respective Summary Table in Section I. This economic analysis, was prepared under the general supervision of James R. Horst (EPA) and John R. Schaub (USDA). Contributing Staff Members included H. Delvo (USDA), D. Graham (USFS), D. Herzog (Univ. of Florida), R. Lee (EPA), E. Lloyd (USDA), G. Ludvik (EPA), D. Mattson (EPA), J. Palmisano (EPA), R. Ridgway (USDA), C. Roy (EPA), C. Schaefer (Univ. of Calif.), M. Shepard (Clemson Univ.), R. Stanton (USDA), C. Tinney (USDA), and L. Zygadlo (EPA).

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I. INTRODUCTION AND SUMMARY

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PURPOSE OF ANALYSIS

This preliminary biological and economic assessment of the insecticide diflubenzuron is intended as an input to the risk/benefit decision by the Administrator of EPA as to the continued registration of diflubenzuron for gypsy moth control and the registration for additional uses under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended (FIFRA) (7 U.S.C. 135 et seq). Diflubenzuron was referred to the Special Pesticide Review Division in the Fall of 1977 for evaluation based on triggers of oncogenicity and adverse effects on the environment. If the risks appear to outweigh the benefits, the Administrator may announce intent to cancel the existing registration and deny the other registrations under FIFRA.

This report was prepared cooperatively by the USDA/State/EPA Diflubenzuron Assessment Team in accordance with the MEMORANDUM OF UNDERSTANDING BETWEEN THE U.S. DEPARTMENT OF AGRICULTURE AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY, effective December 2, 1976.

SCOPE AND APPROACH

This report is a use-by-use assessment of the proposed uses of diflubenzuron. It includes estimates of the quantities utilized, identification of the currently used registered alternatives, a determination of the change in insect control costs associated with the use of diflubenzuron, and evaluation of the regulatory impact upon crop production and retail prices. The uses evaluated are control of boll weevil on cotton; velvetbean caterpillar,

Mexican bean beetle and green cloverworm on soybeans; gypsy moth in eastern hardwood forests; tussock moth in western conifer forests; and mosquito larvae in urban and residential areas and around farm buildings.

Since, with the exception of gypsy moth control, diflubenzuron has not previously been used, the general approach taken in this analysis was to evaluate the impacts of shifting from the currently used insecticides to diflubenzuron at the user level in affected areas and projecting the resulting impacts to the commodity and consumer levels where appropriate. Economic impacts on users were considered at the state/region and U.S. levels. Impacts were estimated on a per-unit basis as well as in the aggregate for specified geographic areas. In the case of gypsy moth control, the above impacts were estimated assuming a shift from diflubenzuron to alternative control measures.

The time frame for analysis is generally one year following possible registration, based on available data from 1972 to 1978. Since, diflubenzuron has not yet been registered, except for gypsy moth, these data were sparse. For the same reason, the suggested application rates and retail price used for diflubenzuron in this analysis are subject to change. If such changes occur, they will affect the cost-of-control impacts estimated in this analysis.

GENERAL BACKGROUND AND USE PATTERNS

Diflubenzuron was discovered by Philips-Duphar B. V. of the Netherlands and has been developed as an insecticide in the United States under license to the Thompson-Hayward Chemical Company, a subsidiary of North American Philips Corporation.

Diflubenzuron is a chitin-inhibiting insecticide which disrupts the development of chitin in immature insects. After ingestion, instars survive until the next molt. Diflubenzuron must be ingested to work and, therefore, is effective primarily on immature foliar feeding insects. Sucking and adult foliar feeding insects are not affected by it (Stanford Research Institute, 1977).

In May, 1976, Thompson-Hayward received a registration on diflubenzuron for the control of gypsy moth. For this use, 895 pounds were used on 25,000 acres of forest land in 1977 (considerably more was used and treated in 1978). This is the total annual usage of diflubenzuron since no other registration for commercial use currently exists.

SUMMARY OF FINDINGS

Overall Impacts

The economic impacts from cancellation of diflubenzuron for gypsy moth control and registration for other uses are summarized in Table I-1. These impacts are not summed to a total impact because some uses have unique features which create non-comparability among the analyses. The detailed procedures, assumptions and implications for each use are specified in each analysis later in this report. The purpose of this subsection is merely to summarize the dominant features of the results.

Table I-1

Overall Summary of Preliminary Biological and Economic Assessment of Diflubenzuron

Use	Annual Extent of Use a/		Economic Impacts on Users		
	Active Ingredient	Area of Treatment	Cost-of-Control Savings	Value of Increased Production	Total
	pounds	1,000 acres	million dollars/yr		
Gypsy Moth	variable b/	variable c/	--	--	--
Cotton	500,000	1,302	10.6	-- d/	10.6
Soybeans	--	3,104	7.6	5.8	13.4
Tussock Moth	variable e/	350 f/	--	--	-5.3 h/
Mosquitoes	--	NE g/	--	--	--

a/ Based on assumptions specified in individual analyses. Since diflubenzuron is not marketed, except for gypsy moth, the area treated historically was not available for any pest other than this one.

b/ Depends largely on size of APHIS eradication program each year. 895 pounds used in 1977 (869 pounds in APHIS program). 6,240 pounds in 1978 in APHIS program (amount used in U.S. Forest Service and state programs is unknown).

c/ 25,000 acres in 1977 (14,479 acres in APHIS program). 107,000 acres in 1978 in APHIS program (acreage treated in U.S. Forest Service and state programs is unknown).

d/ There may be a yield increase resulting from the use of diflubenzuron on cotton. If a yield increase of 5 percent were realized, value of production would increase by $15.6 million.

e/ 37,500 to 100,000 pounds a.i. over a 3-year period.

f/ Not annual. Outbreak requiring treatment is expected only every 8-10 years. Treat this acreage over a 3-year period once an outbreak occurs.

g/ Not estimated.

h/ Savings if carbaryl instead of diflubenzuron is used and carbaryl's possible undesirable side effects are accepted.

[illegible]

[illegible]

For the three uses where economic impacts were estimated, the results are the following: $10.6 million annually for cotton, $13.4 million annually for soybeans, an increased cost of $5.3 for control of tussock moth about every 10 years when the problem occurs in order to avoid possible adverse environmental effects from the only alternative, carbaryl. There may also be an increased impact for cotton of $15.6 million if the use of diflubenzuron increases yield by 5 percent, as expected by entomologists contributing to this assessment.

Use of diflubenzuron to control gypsy moth, the only use for which it is registered, does not provide noticeable economic impacts. It is 20 percent less expensive than carbaryl for use in the eradication program, but is comparably priced to its alternatives for other gypsy moth control programs. However, unlike several of these alternatives, diflubenzuron does not interfere with non-target or beneficial predator insects.

For mosquito control, diflubenzuron does not have cost advantages over its alternatives. However, it is important as a new, efficacious insecticide to control this pest because the mosquito builds up resistance to traditional chemical controls. Currently, only parts of central California are without an effective insecticide, but mosquitoes will become resistant to currently used insecticides in more areas through time.

All the measured impacts occur at the user level. The effects on production are small relative to industry size, so consumer impacts are not anticipated. In general, diflubenzuron does not have cost advantages over alternative insecticides. However, it does have the important advantage of not interfering with beneficial insects.

Gypsy Moth

The only use for which diflubenzuron is currently registered is gypsy moth control. Diflubenzuron is in the same cost range as the other chemicals currently used for gypsy moth population control and defoliation control. It is of equal efficacy, but it offers the added advantage of not being harmful to bees and other potentially beneficial insects.

In areas where chemical control is required to eradicate the gypsy moth from an area into which it has recently been introduced, diflubenzuron is almost 20 percent cheaper than the alternative chemical. It is equally effective. In 1978, USDA planned an eradication program on just over 100,000 acres.

No market or consumer impacts are expected as a result of diflubenzuron's availability or non-availability. Likewise, no Social or Community impacts should be noted, unless new major areas of infestation occur and eradication efforts fail. It is in this regard that the strongest case for diflubenzuron can be made.

Table I-2

SUMMARY OF PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON (DFB) USE ON GYPSY MOTH/FOREST TREES

A. USE:	Hardwood trees and forests
B. MAJOR PESTS CONTROLLED:	Gypsy Moth
C. ALTERNATIVES:	
Major registered chemicals:	RPAR candidates: Carbaryl; trichlorfon; phosmet (Imidan). Non-RPAR candidates: Acephate; malathion; methoxychlor.
Non-chemical controls:	Biological controls: Bacillus thuringiensis (B.t.) and Nuclear polyhedrosis virus (NPV), aerially applied. Other non-chemical controls: parasites and predators; forests stand manipulation (long term only)--neither method has been operationally tested.
State/Federal recommendations:	Diflubenzuron = [illegible] - 1.0 oz. a.i./acre; carbaryl = 1 lb., a.e./acre; trichlorfon = 1 lb., a.i./acre; acephate = .5 lb., a.i./acre; Bacillus thuringienis = 8 bil.I.U./acre (2 applications); Nuclear polyhedrosis virus = 25 Mil.P.U./acre (2 applications).
Efficacy of alternatives:	Preferred alternatives include carbaryl (RPAR), trichlorfon (RPAR), and acephate. Others less dependable. Biological controls erratic; NPV available only in limited quantities. DFB provides some carryover control through ovicidal activity. In most cases other chemicals require annual application.
Comparative performance:	Control of defoliation: Carbaryl, acephate, trichlorfon are superior through quick kill, DFB lags 3-10 days. Population control: Several alternatives about equivalent to DFB. Trichlorfon and acephate are less dependable if rain follows application. Eradication: DFB applied twice (.5 oz. a.i./acre) is preferred for flexibility in timing and reduction of viable eggs. Carbaryl is the only other chemical used; it is also applied twice.
Comparative costs:	DFB is in the same relative cost range as other controls for defoliation programs. For eradication programs, it is approximately 20% cheaper than the only alternative ($4.82 vs. $5.86 per acre).
Conclusions:	DFB is competitively priced, equally effective and is not harmful to bees and other beneficial insects. Acephate and carbaryl adversely affect bees and certain insect parasites. Trichlorfon is of marginal effectiveness when rain follows spraying. All four chemicals provide residual effects for control of staggered egg hatch (2-4 weeks), in favorable weather. Defoliation is greater with DFB because of the slower killing action. Present labeling interpretation on DFB would preclude use in a residential area. Except for these four, other controls are undependable and not used. NPV and B.T. are marginal in effectiveness, show little residual effect, and are more costly.
D. EXTENT OF USE:	All use through federal programs. In FY 1977, 895 pounds of DFB used, 97 percent of which was in APHIS eradication program. 25,000 acres were treated. FY 78 plans indicated use of 6,240 pounds, on 107,[illegible] acres, plus unknown amounts by USFS/States.
E. ECONOMIC IMPACTS:	
User:	Limited to the incremental costs of using alternatives plus the possible losses in control and damages sustained if DFB were cancelled. Comparative costs of population control place DFB at the average for all four preferred chemicals. Choice among chemicals is often made on other grounds than cost as noted above. For eradication programs DFB is preferred because of unwanted bee and parasite/predator impacts of carbaryl. In addition, approximately $1/acre could be saved by using DFB rather than the alternative, based upon a recently announced diflubenzuron price of $2.55 per oz.
Market, Consumer and Macroeconomic:	None expected.
F. SOCIAL/COMMUNITY IMPACTS:	None, short term. Long term could be extensive if any new infestations are not contained.
G. LIMITATIONS OF ANALYSIS:	Operational effectiveness of DFB is based on only two years of field applications. Further reductions in application rates are still being tested. Qualitative and environmental considerations are much more critical than the economic impacts of withdrawal of DFB. These were not analyzed fully since quantitative data are lacking.
H. PRINCIPAL ANALYSTS:	EPA: D. Dudley Mattson, Ph.D., Economist, EAB, BFSD, OPP USDA: Ray Stanton, Ph.D., Economist, ESCS, NRED

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Cotton

Diflubenzuron is not currently registered for use on cotton but application has been made to register it for control of boll weevil. If registered, diflubenzuron would also contribute to the control of the bollworm-budworm complex by not interfering with natural predators of this worm complex.

The regions subject to boll weevil infestation are the Southeast, the Delta and part of the Southwest. Approximately 7.3 million acres are subject to boll weevil infestation in these regions. Of this total, an estimated 3.5 million acres will receive insecticide treatments in an average year, and 1.3 million of these acres would probably receive treatment with diflubenzuron if it was registered.

On those acres where diflubenzuron is estimated to be used, the control costs will be lowered by $3.50 to $18.60 per acre under currently used insecticides. In the aggregate, control costs are estimated to be reduced by $10.6 million. However, a $15.6 million increase in the value of production may also occur, if a 5 percent yield increase is realized from the use of diflubenzuron.

Diflubenzuron is not likely to be competitive with currently used insectcdes for boll weevil control alone, but is generally competitive to control the boll weevil and bollworm-budworm compex jointly. Since diflubenzuron does not interfere with the natural predators of the worm complex, the initial chemical treatment to control these pests can be delayed and fewer applications will most likely be needed throughout the season.

Table I-3

SUMMARY OF PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON USE ON COTTON

A. USE: Cotton

B. INSECTS CONTROLLED: Boll weevil (Anthonomus grandis); contributes indirectly to reduction in bollworm-budworm complex (Heliothis spp.).

C. CURRENTLY USED INSECTICIDES:

Registered insecticides:

Azinphosmethyl	EPN
Methyl parathion	Monocrotophos
Toxaphene + methyl parathion (RPAR)	Malathion

Non-chemical controls: None which compete with chemical controls. However, several non-chemical controls which contribute to boll weevil control exist, including the use of determinant varieties of cotton and the use of pheromone traps in early spring.

Comparative efficacy of currently used insecticides: Equal control of boll weevil is assumed although the efficacy of diflubenzuron over any of its substitutes is not clear. However, unlike the currently used insecticides, diflubenzuron does not interfere with natural predators which provide some control of the bollworm - budworm complex Thus, the initial chemical application to control the worm complex can be delayed and the total number of applications reduced.

Comparative yield effects: No change in yield on a per acre basis is assumed. However, entomologists believe some yield increase will occur with the use of diflubenzuron.

Comparative costs: Estimated annual diflubenzuron treatment costs vary by state from $26.40 to $30.90 per acre. Diflubenzuron is estimated to be generally competitive with currently used insecticides for combined boll weevil/bollworm-budworm complex control. However, it is not likely to be competitive for boll weevil control alone.

Comments: Since diflubenzuron does not interfere with natural predators or biological controls introduced by man, it is a potentially useful boll weevil control agent for use in IPM programs.

D. EXTENT OF USE:

Acreage and active ingredient basis: Approximately ten percent (1.3 million acres) of total cotton producing acreage could be treated with diflubenzuron if it was registered for this use. These 1.3 million acres are centered in Georgia, Louisiana, Mississippi, North Carolina, and Texas. An estimated 500,000 pounds of diflubenzuron would be used to treat this acreage.

E. ECONOMIC IMPACTS: Control cost savings from using diflubenzuron are summarized in the table below. No yield effects are assumed. However, if a yield increase of 5 percent were realized from the use of diflubenzuron, the value of production would increase by $15.6 million.

User:

States	Feasible Acreage	Decrease in Per Acre Control Costs	Total Change In Control Costs
	1,000 acres	dollars	$ million
Georgia	133	15.30-18.60	-2.29
Louisiana	289	3.50	-1.01
Mississippi	713	7.80	-5.53
North Carolina	56	12.30	-0.69
Texas	111	3.90-14.70	-1.03
Total	1,302	--	-10.55

Market: No market impacts will occur if there are no yield impacts as assumed. However, if a 5 percent yield increase were realized, market prices might be reduced minimally.

Consumer: There are no consumer impacts.

Macroeconomic: There are no macroeconomic impacts.

F. SOCIAL AND COMMUNITY IMPACTS: The use of diflubenzuron could further the general introduction of IPM as a farm management technique among cotton growers. Also, 500,000 pounds of diflubenzuron would replace an estimated 13.8 million pounds of current boll weevil and bollworm-budworm suppression materials.

G. LIMITATIONS OF ANALYSIS: The analysis is based on several broad assumptions. The price of diflubenzuron is an estimate, since it has not yet been marketed for this use. There may be yield impacts from using diflubenzuron, but there is little data supporting a differential in yield between diflubenzuron use and that of substitutes. Also, harvested cotton acres are erratic. Base acres for the analysis were not estimated from current usage, but rather from a multi-year weighted average characterization of cotton production. Finally, much of the data came from questionnaire responses; as such these data are not validated.

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Soybeans

Diflubenzuron is not currently registered for use on soybeans, but application has been made to register it for control of velvetbean caterpillar, Mexican bean beetle and green cloverworm. These three pests occur in relatively distinct geographic regions. The velvetbean caterpillar occurs primarily in the Southeast and Delta regions, the Mexican bean beetle is a problem primarily in the mid-Atlantic states, and the green cloverworm is a problem primarily in the North Central region.

Diflubenzuron selectively controls these pests with one application per season. This selectivity has the advantage of not interfering with natural predators but also has the disadvantage of not controlling other insect pests of soybeans.

The total impact of using diflubenzuron to replace currently used insecticides is estimated to be $13.4 million annually, partially from control cost savings and partially from production increases. All of these impacts occur at the user (farm) level and are nearly maximum estimates, based on the assumption that diflubenzuron will replace currently used insecticides on most (exact specifications in the analysis, chapter IV) of the soybean acreage currently treated with insecticides for these three insect pests.

Essentially all of the economic advantages of diflubenzuron occur at moderate and high levels of infestation of velvetbean caterpillar. Infestations at these levels occur annually, through time averaging 45 percent of the acreage infested with velvetbean caterpillar and 37 percent of the acreage infested with all three pests. This acreage accounts for 98 percent of the savings ($7.4 million) and 100 percent of the increased value of production ($5.8 million).

Table I-4

SUMMARY OF PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON USE ON SOYBEANS

USE: Soybeans

INSECTS CONTROLLED: Velvetbean caterpillar, Mexican bean beetle, green cloverworm

CURRENTLY USED INSECTICIDES:

Registered insecticides analyzed:

Insecticide	Insect: Velvetbean Caterpillar	Mexican Bean Beetle	Green Cloverworm
Carbaryl	x[a/]	x	x
Methomyl	x	x	-
Malathion	-[b/]	-	x
Methyl Parathion	x	-	-
Toxaphene + M.P. (RPAR)	x	-	-
Toxaphene (RPAR)	-	-	x

a/ "x" signifies selection as an alternative for the respective pest(s)
b/ "-" signifies non-selection as an alternative

Non-chemical controls: None which are commercially feasible at the current time.

Comparative efficacy of currently used insecticides: Equal control to diflubenzuron except for moderate and high infestations of velvetbean caterpillar. Diflubenzuron is effective with one treatment per year. Two or three treatments (5 treatments in Florida) of the currently used insecticides are commonly needed to control infestations of velvetbean caterpillar. Both Mexican bean beetle and green cloverworm can be controlled with one treatment of the currently used insecticides.

Comparative yield effects: None in areas infested with Mexican bean beetle or green cloverworm. In areas infested with velvetbean caterpillar, diflubenzuron estimated to increase soybean yield by 0.41 bushels per acre (moderately infested areas) and 1.44 bushels per acre (highly infested areas).

Comparative costs: Annual treatment costs with diflubenzuron range between $4.25 and $5.75 per acre. Annual treatment costs for currently used insecticides range from $3.87 to $29.00 per acre.

Comments:

1. Currently used insecticides effectively control other insect pests of soybeans in addition to the three pests in this analysis. Diflubenzuron does not.

2. Some currently used insecticides kill naturally occurring predators in addition to the pests, a situation which may allow resurgence of the pests to damaging levels shortly after treatment. Diflubenzuron does not harm these beneficial predators.

EXTENT OF USE: None used. Diflubenzuron not registered for use on soybeans.

1976 usage of some currently used insecticides are given below:

Insecticide	Active Ingredient	Acres Treated
	1,000 lbs	1,000 acres
Carbaryl	3,668	2,923
Methomyl	483	865
Malathion	--	--
Methyl Parathion	713	677
Toxaphene	2,206	488

U.S. sobyean acreage treated with all insecticides for all insect pests: 4 percent (1966); 8 percent (1971); 10 percent (1976)

Table I-4 (Cont'd.)

ECONOMIC IMPACTS:

User impacts:

Treatment cost savings per acre from using diflubenzuron: none in controlling Mexican bean beetle to maximum of $17.80 in Florida to control velvetbean caterpillar.

Aggregate user impacts: majority of savings and all production effects occur in areas with velvetbean caterpillar infestation.

Summary of Annual User Impacts by Insect and Region

Insect and Region	Treatment Cost Savings	Value of Increased Production	Total
	---------------1,000 dollars---------------		
Velvetbean Caterpillar			
Florida	2,690	1,092	3,782
Southeast	4,133	3,740	7,873
Delta and Southern Plains	650	988	1,638
Total	7,473	5,820	13,293
Mexican Bean Beetle	-61	—	-61
Green Cloverworm	176	--	176
Total	7,588	5,820	13,408

Consumer impacts:

None expected

LIMITATIONS OF ANALYSIS:

1. Manufacturer's suggested retail price was used for diflubenzuron in this analysis rather than market price.

2. No market share data were available for diflubenzuron. Therefore, a particular set of strategies for the use of diflubenzuron were developed which maximize the acreage on which diflubenzuron was assumed to be used.

3. The acreage infested data used in this analysis were subjectively determined by entomologists in the states affected.

PRINCIPAL ANALYSTS AND DATE:

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The single-treatment cost per acre with diflubenzuron lies within the range of single-treatment costs of the currently used insecticides. The major advantage of using diflubenzuron is its ability to provide season-long control of velvetbean caterpillar with only a single treatment, regardless of the level of infestation, whereas currently used insectides require additional treatments at higher infestation levels. Both Mexican bean beetle and green cloverworm can be controlled with a single treatment of the currently used insecticides or diflubenzuron.

Tussock Moth

The Douglas fir tussock moth is a forest insect found primarily on the inland range of Douglas fir and true fir in the western states. It periodically reaches epidemic levels and causes widespread forest damage. There is no completely satisfactory registered chemical control for the tussock moth. Carbaryl, the only registered chemical, may have undesirable side effects at registered dosage rates. The tussock moth reaches epidemic population levels only about once every 9-10 years. Until such a population buildup there is little need for control.

During periods of severe tussock moth population pressure, which may last 2-3 years, defoliation and tree mortality can be severe. Even trees that do not die suffer serious growth loss. Dead trees can often be salvage logged, but they have a lower-than-normal price. Dead trees also increase the risk of forest fires and cause a resultant increase in fire prevention and control costs. In cases where existing regeneration is destroyed, replanting of the stands is necessary. In developing the economic estimates, a range of possible management and biological conditions was

analyzed. When the economic impacts of all of these conditions are summed, the average benefit from controlling tussock moth with diflubenzuron is estimated to be $25.06 million, compared to no control. The average benefit from using carbaryl, compared to no control, is estimated to be $30.32 million, assuming the possible undesirable side effects are accepted as being cost-free. Thus, with a $5.3 million smaller benefit, diflubenzuron has no economic advantage over carbaryl.

Table I-5

SUMMARY OF PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON (DFB) USE ON DOUGLAS FIR TUSSOCK MOTH/FOREST TREES

USE: Presently experimental only, registration not yet applied for.

MAJOR PESTS CONTROLLED: Douglas Fir Tussock Moth

ALTERNATIVES:

Chemical alternatives: Carbaryl (RPAR candidate)

Non-chemical alternatives: Bacillus thuringiensis, Nucleopolyhedrosis virus

Efficacy and comparative performance of alternatives: Bacillus thuringiensis is not consistently effective. Nucleopolyhedrosis virus is not commercially available. The only registered alternative carbaryl (of comparable efficacy) is felt to be undesirable for widespread application because of the possible toxic effects on parasites/predators of tussock moth and other beneficial insects.

Conclusion: No suitable, effective, available alternative exists. Carbaryl has possible ecological side effects at the dosage necessary for comparable efficacy.

EXTENT OF USE: No current active infestations. Outbreaks assumed to cover 500,000 acres expected approximately every 10 years. Economic damage would require treatment of 350,000 acres with 43,750 - 87,500 lbs. a.i. of DFB or 700,000 lbs. a.i. of carbaryl.

ECONOMIC IMPACTS:

Economic analysis: It is assumed the expected outbreak would have a biological impact upon the infested acreage similar to the 1972-74 infestation. The biological data were then applied to a range of typical stand, growth and management conditions to determine high and low estimates of the dollar value of mortality, salvage and growth loss on mature and immature timber.

Benefits of Control with Insecticides, Compared to No Control

	DFB		Carbaryl	
	Range[a/]	Midpoint	Range[a/]	Midpoint
	---million dollars---			
Losses prevented:				
timber value	13.24-19.35	16.32	13.24-19.35	16.32
fire protection	6.0 - 8.5	7.25	9.60-13.50	11.55
replanting	3.00- 7.49	5.24	3.00- 7.49	5.24
Total losses prevented	22.24-35.34	28.79	25.84-40.35	33.09
Control costs	2.84- 4.62	3.73	2.77- 2.77	2.77
Net benefits	19.40-30.72	25.06	23.07-37.58	30.32

a/ Chosen to reflect the variety of biological and management conditions of the region.

The above table shows that diflubenzuron does not have an economic advantage over carbaryl. Rather, comparison of the mid-point net benefits of the two chemicals indicates that carbaryl has a $5.3 million economic advantage over diflubenzuron.

Macroeconomic impact: Not considered.

Microeconomic impact: Local severe impacts possible. Disruption of growing cycle and timber harvest patterns upon which some small communities are totally dependent. Initial salvage sales of timber volumes in excess of local mill capacity, later periods of greatly reduced cut.

LIMITATIONS OF ANALYSIS: Major dependence on USFS data for 1972-74 outbreak. Fire prevention and control, and reforestation costs were estimated. Neither carbaryl nor DFB have had wide scale field tests for efficacy or control of defoliation and damage. Impacts are presented for a hypothetical infestation of 500,000 acres with 350,000 acres requiring treatment.

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Mosquitoes

Mosquitoes transmit a variety of human and animal diseases including malaria, yellow fever, various strains of dengue and dengue-haemorraghic fever, and a large number of various types of encephalitis. Additionally, mosquitoes cause a great deal of discomfort which can affect the productivity of animals and decrease the enjoyment of outdoor recreational activities for humans.

There are a variety of control methods to reduce mosquito populations. The principal methods are source reduction of breeding areas and insecticides. Neither method is completely satisfactory. Source reduction is costly and not always feasible. With currently registered pesticides some sites cannot be treated and resistance has developed in some areas.

Diflubenzuron has been demonstrated experimentally to be an effective mosquito larvicide, but is not registered for this purpose. The potential value of diflubenzuron for mosquito control in the U.S. is difficult to estimate. Human health is involved and placing a quantitative value on either human health or life is difficult at best. Given the fact that serious outbreaks of diseases such as malaria or encaphalitis are not prevalent in the U.S., on an economic or human health basis a clear cut justificaton for the use of diflubenzuron is not readily apparent. However, if a serious or significant outbreak of mosquito-conveyed diseases should occur, the value of diflubenzuron would be large. For example, following an outbreak of encaphalitis in 1952 there were 50 fatalities and a number of children who were affected suffered permanent brain damage. Most of the children who had severe cases became permanent wards of the state. In California, as of January 1, 1978, the average cost per patient in mental hospitals was $1,800 per month.

Presently there is about a 400,000 acre area in California where Culex, Tarsalis, the vector of western equine and St. Louis encephalitis is resistant to organophosphate larvicide.

In periods of flooding, control is essential to prevent serious outbreaks. Except for a few areas such as this one in California, given the present effectiveness of less costly alternatives and the present restrictions on the proposed diflubenzuron label, diflubenzuron would not be or could not be used in over 95 percent of the habitat.

Table I-6

SUMMARY OF PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT
OF DIFLUBENZURON (DFB) USE FOR MOSQUITO CONTROL

A. USE:	Human and domestic animal health and comfort (excluding crops, areas used for food, feed, hay, pasture, potable water, and water for livestock).
B. MAJOR PEST CONTROLLED:	Mosquitoes
C. ALTERNATIVES:	
Major registered chemicals:	Chlorpyrifos, fenthion, methoprine, parathion, temophos, diesel oil, DFB (temporary permit).
Non-chemical controls:	Mosquito-eating fish, control of aquatic vegetation; elimination of breeding habitat.
Efficacy of alternatives:	Fenthion, chlorpyrifos, parathion effective against larvae and adults; oil, temophos, methoprene effective against larvae. Methoprene not effective against *Culex* larvae. High resistance to organophosphorus insecticides in central California.
Comparative performance:	Non-chemical controls and oil not always feasible or desirable, as in wildlife refuges. Organo-phosphorus chemicals may be toxic to fish and crustaceans.
Comparative costs:	Chemical costs per acre per treatment: parathion, $0.20; chlorpyrifos, $0.60; temophos, $0.60; fenthion, $0.70; DFB, $1.20; methoprene, $2.00; oil, $5.40.
Conclusions:	DFB can be an effective control for mosquitoes where resistance is a problem, but label limitations restrict its use to less than 5% of current breeding habitats.
D. EXTENT OF USE:	
Quantity of chemical:	Data not available by specific chemical.
Expenditures:	Total spending by public agencies for mosquito control estimated at $69 million in 1977.
Acres treated:	Estimated 5 million acres treated by larvicides in 1977; 30.5 million acres treated with adulticides (Figures may understate use); 22% are in southwest.
E. ECONOMIC IMPACTS:	
User:	Impacts expected to be negligible except in areas with high resistance problems and where allowed by the label.
Consumer/Social:	Possible impacts only in areas with high resistance problems. Some livestock production loss could occur, as well as decreased enjoyment and use of outdoor recreation facilities. Impacts in this area are expected to be minor except in the case of a human and/or equine disease epidemic.
F. LIMITATIONS OF ANALYSIS:	Lack of data on use of each control method.
G. PRINCIPAL ANALYSTS:	EPA Clara Roy, Economist EAB, BFSD, OPP USDA John Schaub, Lead Economist ESCS, NRED

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II. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON FOR GYPSY MOTH ON TREES

II. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON USE FOR GYPSY MOTH

INTRODUCTION

Since its introduction in 1969 in Massachusetts, the gypsy moth has spread over most of the northeastern states. Its range now includes the New England States, New York, Pennsylvania, New Jersey, and the northern portions of Delaware, Maryland and a small portion of West Virginia.

The gypsy moth can develop into epidemic populations which result in severe defoliation of a number of native hardwoods and occasional softwoods. In 1977, moderate to heavy defoliation occurred on nearly 1,600,000 acres. The preference of the gypsy moths for oaks, one of the more abundant native genera can result in extensive defoliated forest areas. Other species commonly attacked include: apple, alder, aspen, basswood, hawthorn, willow, and birch. Several native softwoods are sometimes attacked.

CURRENT USE ANALYSIS

Registrations and Recommendations for DFB & Alternatives

Seven chemicals are registered for use for gypsy moth control and the following four are recommended at rates shown on the labels:

- diflubenzuron (DFB), .03-.06 pounds a.i. per acre;
- trichlorfon, 1 pound a.i. per acre;
- acephate, .5 pound a.i. per acre;
- carbaryl, 1 pound a.i. per acre.

Three additonal chemicals are registered: phosmet, malathion, methoxychlor. These chemicals are not known to be used.

Two biological controls are registered: _Bacillus thuringiensis_ (B.t.), 8 billion international units (B.i.u.) per acre; nuclear polyhedrosis virus, (NPV) 25 million potency units (M.P.U.) per acre. These are sprayed in a manner similar to the chemicals. These controls have limited use and availability. NPV was registered for use by the U.S. Forest Service in April 1978. Testing and further development of formulation and applications are continuing before general use recommendations can be made.

Other controls include parasite-predator release and forest stand manipulation. No large scale parasite-predator rearing programs presently exist to permit operational use. Forest stand modifications may also be possible. Recent investigations have identified some of the stand criteria that appear to be prerequisites to problem tree mortality following defoliation by the gypsy moth. Manipulation of stand/composition through selective thinning can remove trees that are susceptibel to infestation by gypsy moth (USFS/APHIS, 1978). New plantings of less susceptible species are also possible.

Control Efforts - Past and Present

Early efforts to control the gypsy moth were aimed at eradication and relied heavily on the use of lead arsenate. These treatments were abondoned during the 1940's as the gypsy moth continued to spread. Post World II control efforts were centered on the use of DDT. The DDT control program was phased out approximately 1964 because of increasing concern for environmental effects. From 1962 to 1967 major reliance was placed on carbaryl, with approximately 2 million pounds used during this period. During the past 10 years, 3 additional chemicals have been developed and registered: trichlorfon, acephate, and diflubenzuron (DFB). Most recent control programs have

depended heavily on three of these chemicals, carbaryl, trichlorfon, and diflubenzuron, with lesser use of acephate. The attached summary table presents the use of these four chemicals for the two major program efforts discussed below.

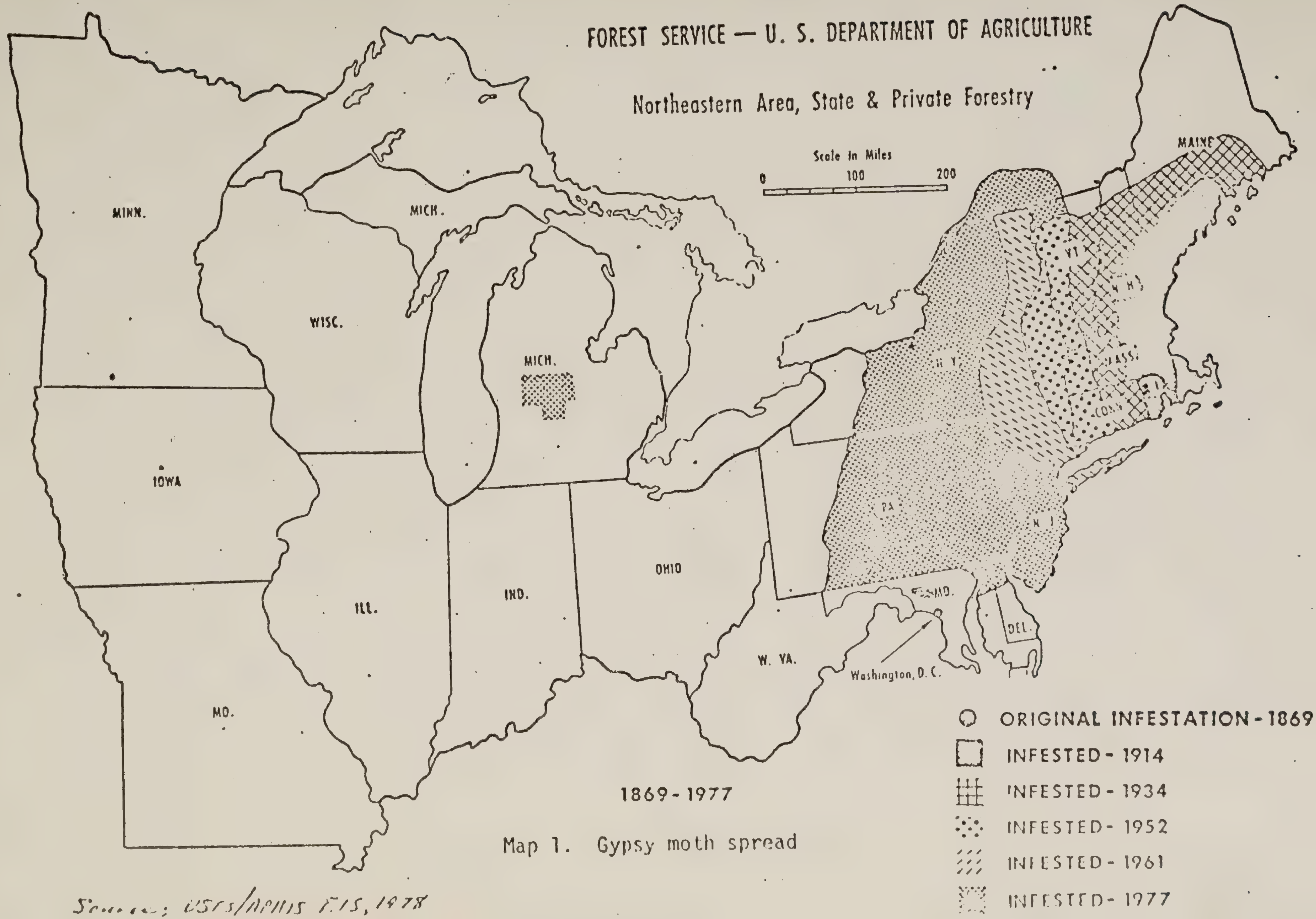
• Current Control Programs

The present gypsy moth problem occurs in two geographic areas, the endemic Northeast and scattered infestation pockets in other areas (Figure II-1). The general infestation area in the northeast has exhibited a gradual spread from the original point of introduction, now covering the identified states. The potential for continued spread of gypsy moths covers almost the entire eastern 1/3 of the country and suitable habitats in the western states. The artificial migration of gypsy moth egg masses and/or pupae can result in successful establishment wherever suitable host trees are available.

Cooperative U.S. Forest Service/State Suppression Program

The policy for suppression projects is to initiate direct suppression only in high use recreational areas, residential areas, and high value forest land where damaging levels of gypsy moth populations develop (USFS/APHIS, 1978). This program is designed to reduce gypsy moth nuisance and defoliation. It is not intended to stop the outbreak nor prevent the spread of the insect. Suppression is carried out in Pennsylvania and New Jersey and is presented in the summary table for 1977. High use, high value areas include campgrounds, recreational roadsides, rural residence areas and rural communities. Control efforts are initiated when severe infestations

Figure II-1



Map 1. Gypsy moth spread

Source: USFS/APHIS F.I.S, 1978

develop which could result in heavy defoliation. High value forests are treated when surveys indicate repeated defoliation may occur resulting in heavy mortality of high value timber or scenic forests.

Programs of The Animal Plant Health Inspection Service, USDA

Two programs by this agency are directed toward prevention of spread and establishment of the gypsy moth into areas separated from the northeast infestation area. These are: (1) A control program attempting to prevent the accidental and artificial spread of egg masses and larvae attached to vehicles; (2) eradication actions intended to destroy outlying infestations as discovered. These programs employ only two chemicals, diflubenzuron (DFB) and carbaryl.

The control program is directed principally at areas where recreational vehicles, mobile homes or military and other cargo move from infested areas to possible locations of new infestation, and relies primarily on carbaryl by either ground or aerial application. Control programs were carried out in 6 northeastern states on a total of 405 sites in 1977. A total of 26,186 acres were treated (Table II-1). Three New England states received ground treatments only, on a total of 1,110 acres. Sites in New York, New Jersey and Pennsylvania were treated by ground and air for a total of 25,076 acres. This control program used carbaryl exclusively.

Eradication of outlying infestations utilizes DFB as the principal control, applied twice, 6-10 days apart, usually by air. An application of carbaryl may also be applied to portions of these eradication areas. Apparently successful eradication has been obtained at Palos Park, Illinois (two years since treatment with no survey findings of moths). A similar eradication was performed at San Jose, California in 1976 with no reported moths in 1977.

Table II-1

Acres treated and chemicals applied for Gypsy Moth Control, by chemical and program

Year and Program	Area Defoliated	Area Treated	Chemical Used							
			DFB		Carbaryl		Trichlorfon		Acephate	
	----------acres----------		acres treated	pounds used	acres treated	pounds used	acres treated	pounds used	acres treated	pounds used
FY 77										
USFS/States	1,598,000	96,146	10,736	415	12,800	9,591	71,922	71,922	700	350
APHIS	--	36,134	14,471	869	26,186	26,186	--	--	--	--
Total all programs	1,598,000	132,280	25,215	1,284	38,986	35,777	71,922	71,992	700	350
FY-78 Plans	Suppression: USFS estimates 168,585 acres of control in PA, NJ, MD using several chemicals; APHIS programs plan for 39,585 acres of treatments in the Northeast. Eradication on 107,000 acres using 6,240 pounds of DFB in Michigan.									

Source: USDA

The following, prepared by John Kennedy of the APHIS, summarizes the development of plans and illustrates the evolution of control efforts expected in the future.

> The Animal and Plant Health Inspection Service (APHIS) is developing a comprehensive gypsy moth pest management program in concert with the Forest Service, Science and Education Administration, Federal Research, (FR-SEA), and the States. The various components of the program (regulatory, suppression, research, etc.) will be unified to deal with the gypsy moth in a coordinated manner at all levels.
>
> Included in this comprehensive program is the APHIS component involving operational containment of the gypsy moth to begin in the spring of 1979. Among the strategies that will be incorporated is the leading edge concept to retard the natural spread of the pest. It will be a management program based on extensive survey, intervention with various techniques, and evaluation of the effect of the intervention.
>
> DFB is proposed for use in the intervention for treatment of foci of infestations located along the leading edge. The pesticide, DFB, was chosen because it will fit into an integrated approach since it will have little or no effect on the parasites and bees and has little effect on the other environmental factors. Other chemicals proposed either affect the parasites or bees or are not as effective as DFB, cost much more, require two applications, or have adverse effects which would not complement an integrated approach. (Note comparative effects, Table II-2.)
>
> By lowering the gypsy moth populations using a chemical such as DFB, the parasites will not be affected, raising the ratio of parasites to gypsy moths and the possibility of stabilizing the gypsy moth populations at a manageable level. This, along with the other positive factors mentioned, lead us to believe that such an integrated control is possible. Without this material, the integrated approach would be less effective and much more costly. Given the material, chances for success are increased dramatically and cost of the overall project would be held down (Kennedy, 1978).

PERFORMANCE EVALUATION OF DIFLUBENZURON AND ALTERNATIVES

Pest Infestation and Damage

Gypsy moth infestations occur typically in epidemic numbers in localized areas, distributed irregularly throughout the Northeastern states (see Figure II-1). Forests with a predominance of oak, especially when situated on ridges, are often favored. Dryer, rocky sites are subject to mortality from repeated defoliation.

Hardwood tree mortality is directly correlated with the number of successive years of heavy defoliation. Two or more years may cause 50 - 75% mortality. The white oaks followed by gray birch and several red oak species are the most susceptable. Hemlock and white pine (softwoods) may be killed by a single heavy defoliation. Repeated partial defoliation reduces radial growth by as much as 67% (Fairchild et. al, Draft Assessment, 1978).

The gypsy moth completes one generation a year, overwintering as egg masses attach to trees, stones, walls, logs, and other outdoor objects. Eggs hatch from late April to early May, larvae pupate late in June or early in July. Adults emerge 10-14 days later. Only males are capable of flight. The spread of gypsy moth is accomplished in two ways: 1) wind blown dispersal of the first stage larvae, and 2) transport to new areas of later stage larvae, pupae or egg masses. The latter stages are transported by mobile homes, campers, logging trucks, etc.

Comparative Performance of Control Agents

This section addresses four preferred chemical controls and two biological controls which are, or show promise of being, operationally useful. Because of the several purposes (goals) for gypsy moth control, it is necessary to make selections among the control agents based on their characteristics as related to particular program goals (Table II-2).

Population Control

Population control is achieved when retreatment is not required the second year. Carbaryl (at 1.0 pound/acre) and acephate (at .75 pound/acre an experimental rate) have efficacy nearly equal to DFB (at .03 pounds/acre) judging from egg mass reduction. In addition, DFB has an ovicidal effect which provides population control into the next generation. Trichlorfon and acephate may be marginal in some cases, if rain follows application before egg hatch has been completed. Other registered chemicals are not as effective and not used. Biological control agents (B.t., NPV) are known to be effective when carefully and precisely formulated, mixed and applied. They are not commercially available in quantity and are high priced. Their effective use on chosen sites is complicated by precise timing requirements, selective site conditions, the expected health and numbers of the emerging pest generation, and the short effective life of the controls after application. Some technical problems of formulation and application method remain to be solved prior to widespread adoption. It is felt by some researchers that these controls, being highly specific to the gypsy moth and therefore environmentally desirable, will find their most useful role in IPM programs now being developed (Lewis, 1978, Personal Communication).

Table II-2

Comparative Effects of Control Agents Used on the Gypsy Moth

CHARACTERISTICS	Diflubenzuron	Trichlorfon	Carbaryl	Acephate	*Bacillus thuringiensis* (B.t.)	Nuclear Polyhedrosis Virus (NPV)
I. OPERATIONAL PERFORMANCE						
A. RPAR Candidate	X	X	X	-	-	-
B. Tolerance established on agricultural crops	-	X	X	X	-	-
C. Dosage (lbs. a.i./acre	.03 - .06	1.0	1.0	0.5	8 Bi.u.[1/]	25 MPU[1/]
D. No. of Applications	1	1	1	1	2	2
II. ACTIVITY						
A. Contact Poison	X	X	X	X	-	-
B. Stomach Poison	X	X	X	X	X	X
C. Rapid Knockdown & Mortality	-	X	X	X	-	-
D. Foliage Protectant[2/]	X	X	X	X	X	X
E. Ovicidal Activity	X	-	-	-	-	X
F. Population Control[2/]	X	X	X	X	-	-
G. Pre bud-break Control	X	-	-	-	-	-
III. FATE IN THE ENVIRONMENT						
A. Long Persistance on Foliage	X	-	X	-	-	-
B. Short Half-Life - Water	X	X	X	-	X	X
- Soil	X	X	-	X	X	X
IV. ENVIRONMENTAL EFFECTS						
A. Adverse Effects on non-target Insects (direct):						
- parasites & predators	-	X	X	X	-	-
- pollenating insects	-	-	X	X	-	-
B. Adverse Effects on Aquated organisms (direct):						
- invertebrates	X	-	X	X	-	-
- fish	-	-	-	-	-	-
C. Temporary Territory Abandonment by Birds	-	X	X	X	-	-

1/ B.i.u. = Billion international units.
MPU = Million Potency Units

2/ "Foliage protection would be achieved by definition when refoliation was prevented. Refoliation, specifically in oaks, occurs when a tree or portions of it are more than 50 percent defoliated. Population control was defined as achieved when retreatment is not required the following year. It was agreed that there may be foliage protection without population control; however, for successful population control, foliage protection is assumed to be a necessary component."

Source: Gypsy Moth Program Efficacy Workshop, 1974.

Foliage Protection

Achieving protection of current year foliage requires a fast acting control, applied at the earliest effective time, taking into account the variable time of egg hatching. Egg hatching may begin early on warm sites, e.g. near tree tops or in open stands, yet be delayed 2 weeks or more on cool sites, e.g. north slopes, or under heavy shade. Thus a control which remains effective longer yet kills young larvae dependably is preferred. Compared to DFB Carbaryl again ranks higher. DFB can be applied pre-budbreak, but may permit longer feeding in cool weather, thus resulting in delayed foliage protection by larvae already hatched at application time. Ground applications must be for heavy human use areas which have several layers of foliage.

Non-Target Effects

DFB has little or no effect on gypsy moth parasites, predators, or bees. Carbaryl and acephate are toxic to bees and many gypsy moth parasites. Trichlorfon is selectively toxic to some parasites, but is not highly toxic to bees.

Special Problems

The DFB label was interpreted by the EPA to mean that use will be restricted to forested areas and cannot be used in communities. The DFB label also specifies the application of one treatment per year. Carbaryl can be used in communities if residents are warned of possible hazards. Acephate and trichlorfon may be used in residential areas.

ECONOMIC ASSESSMENT

Profile of Impact Areas

Economic impacts of gypsy moth infestations are felt in heavy recreational use areas and in some residential areas. Impacts on the timber industry are serious only when repeated heavy attacks on high value stands result in mortality and/or extensive reduction of growth. Timber values in general are low because timber management in most of the region is usually extensive (as opposed to intensive). Exceptions occur on highly productive sites supporting large trees of commercially valuable species, e.g. white oak (McCay and White, 1973). In contrast to low timber value, the amenity values of healthy forests are generally high, deriving from recreation and tourism. Impact on these amenity values may be severe since defoliation and nuisance numbers of larvae coincide with the peak summer use season of June and July.

User Impacts

The control of the gypsy moth focuses on those areas of heavy human use and on high value forests. Several chemical pesticides have been effectively used to reduce defoliation and the nuisance problems caused by maturing larvae. Mortality in severe cases of repeated heavy defoliation may affect property values for homes and recreation areas.

In a study of recreation areas and homesites suffering Gypsy Moth attacks, Moeller et.al. (1977) reported losses of recreation use of 54-180 person-days per year per property. Losses in recreation use were reported most often by home owners, less often by managers of recreation areas. Causes of loss were attributed mainly to nuisance and defoliation.

Present control programs are reasonably effective using one or more of the four preferred chemicals. Scouting to locate areas of anticipated epidemic populations, through use of pheromone traps for flying males, and counts of egg masses in the fall, permits accurate targeting of these control efforts.

Cancellation of DFB would have a modest effect on these control programs (Table II-3). Of greater concern would be the possible unwanted side effects of carbaryl and acephate (on bees and the parasites/predators of the gypsy moth), or the uncertain control from trichlorfon and acephate when rains follow application.

Of still greater concern is the possible loss through cancellation of 2 of the 3 remaining preferred chemicals: Carbaryl, and trichlorfon--are scheduled for RPAR examination. Program managers and researchers all agree that DFB, for several reasons, can be expected to provide superior control over the other pesticides now used. In addition, they expect that continued refinement of formulations and application methods will lead to more effective as well as more efficient population control in the future. The two years of limited use of DFB has been insufficient to complete these operational refinements.

The use of DFB for eradication efforts (San Jose, California and Michigan) has apparently been very effective, and has resulted in a minimum of unwanted side effects.

A further effect of the loss of DFB would be to set back or handicap the proposed integrated approach to containment of the gypsy moth spread. The combination of characteristics of DFB makes it the best available chemical suited to a program which will complement the natural and biological controls.

Table II-3

Estimated Cost of Gypsy Moth Control on Eradication per acre, by type of Control, 1978

	DFB	Carbaryl	Trichlorfon	Acephate	B.t.	NPV
Chemical and total costs/ac./year using application rates above, aerial applications:						
Chemical costs per acre/applic., (dollars)	2.55	1.79	3.66	2.30	5.75 - 11.50	9 - 18
No. of applications						
control:	1	1	1	1	1 or 2	1 or 2
eradication:	2	2	-	-	-	-
Total control costs/acre/year, dollars:[a]	3.69[b]	2.93	4.63	3.44	6.89 - 13.78	10.32 - 20.64
Total eradication[a]	4.82[c]	4.07	-	-	-	-

a/ Includes application cost of $1.14 per application.
b/ 1 application of 1 oz.
c/ 2 applications of .5 oz.

Market and Consumer Impacts

Due to the minor and variable impact upon timber production and the numerous alternative treatments available no market or consumer impacts are anticipated.

Limitations of Analyses

Operational effectiveness of DFB is based on only two years of field applications. Further reductions in application rates are still being tested. Qualitative and environmental considerations are much more critical than the economic impacts of withdrawal of DFB. These environmental considerations were not a part of this report.

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III. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON FOR BOLL WEEVIL CONTROL ON COTTON

III. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON ON COTTON

INTRODUCTION

Cotton is one of the most important crops grown in the United States. Approximately 12 million acres are planted annually. The value of cotton production for 1974, 1975, and 1976 was $2.3, $2.0, and $3.3 billion respectively.

The Cotton Belt in the United States is comprised of four regions along the Southern half of the country. The Southeast region includes Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama; the Delta region includes Missouri, Arkansas, Tennessee, Mississippi, Louisiana, and Kentucky; the Southwest region is comprised of Texas and Oklahoma; and the West region includes California, Arizona, New Mexico and Nevada.

A variety of insect pests infest cotton, but those of major concern in this analysis are the boll weevil and the bollworm-tobacco budworm complex. Application has been made to EPA for registration of diflubenzuron to control boll weevil. If registered, its use would also contribute to control of the bollworm-tobacco budworm. Unlike the currently used insecticides, diflubenzuron does not interfere with natural predators of this worm complex.

BIOLOGICAL ASSESSMENT

Major Cotton Insects

The boll weevil, Anthonomus grandis grandis Boheman, is the cotton insect controlled by diflubenzuron (Dimilin™). This pest infests two-thirds of the cotton acreage extending from the eastern two-thirds of Texas and Oklahoma through the Delta and Southeast regions, causing severe yield losses when uncontrolled. Treatment measures for this pest are required annually from Texas to the Atlantic Seaboard. Table III-1 indicates the cotton acreage subject to boll weevil infestation by region.

Boll weevil populations require food and favorable weather to increase. Cotton squares (compared to cotton bolls) are the preferred medium for egg-laying and provide a food source for development of the immature weevil. A mean temperature in the low 80's is optimal for rapid weevil population increases. Under such favorable conditions insect populations increase 2.5-fold weekly. Dry weather may reduce this rate drastically. At a 2.5-fold weekly rate of increase, the seasonal weevil population would increase approximately 100-fold in six weeks and 1,600-fold in nine weeks.

The second major insect pest of cotton in the regions of concern (Texas to the Atlantic Seaboard) is the bollworm-budworm complex, Heliothis zea (Boddie) and H. virescens (Fabricius). Other pests of cotton include thrips, aphids, cutworms, plant bugs, flea hoppers, and spider mites.

Table III-1

Cotton Acreage Subject to Treatment for Boll Weevil Infestations

Region	Acres Planted[a/]	Extensive (Maximum) Infestation[b/]	Average (Weighted Average Annual) Infestation[b/]
	------------------- 1,000 acres	-----------------	-----------------
Areas subject to boll weevil			
Southeast	1,069	1,060	963
Delta	3,735	2,019	1,298
Southwest (east)	2,448	1,446	1,193
Subtotal	7,252	4,522	3,454
Other growing regions			
Southwest (west)	2,762	-	-
West	1,533	-	-
Subtotal	4,295	0	0
Total	11,547	4,522	3,454

a/ USDA, ESCS. 1978. Crop Production Annual Summary. CrPr2-1 (78).
b/ Estimated by Federal/State/EPA Diflubenzuron Assessment Team for Cotton.

The most damaging of these pests are the boll weevil and the bollworm-budworm complex. It has been reported that if thrips, plant bugs, and spider mites are not treated the yield losses would be less than 10 percent. However, if boll weevils and bollworm-budworms are not treated yield losses could be so great that harvesting the crop would not be profitable (DeBord, 1977).

In addition to insects which damage cotton, beneficial insects are also associated with the crop. The importance of predators in regulating populations of bollworm-budworms has been recognized for many years (Quanintance and Brues, 1905; Fletcher and Thomas, 1943; Ewing and Ivy, 1943;; Whitcomb and Bell, 1964; vanden Bosch and Hagen, 1966; Lingren et al, 1978). Ridgway (1969) found in Texas that 10 to 15 species of beneficial insects are probably the principal regulators of budworm-bollworm populations. Some of the more important predators are the big-eyed bugs, Geocoris spp.; damsel bugs, Nabis spp.; flower bugs, Orius spp.; green lacewings, Chrysopa spp.; and lady beetles, Hippodamia spp. and Coelophora spp. Under natural conditions these beneficial insects frequently maintain bollworm-budworm populations below injurious levels early in the season. The use of selective insecticides which do not destroy these predators and parasites not only conserves naturally occurring beneficial insects but also allows the supplemental releases of additional predators.

Currently Used Insecticides

Table III-1 presents the geographical extent of boll weevil infestation subject to treatment. A total of 7.3 million acres of cotton are infested with boll weevil, but all will not necessarily require treatment. Of this total acreage, 4.5 million acres are estimated to receive insecticidal treatments for boll weevil during an extensive or worst case infestion year.1/ The average of all years shows that approximately 3.5 million acres receive insecticidal treatments.

The presently used insecticides for boll weevil control and bollworm-budworm are listed in Table III-2. These insecticides are predominantly organophosphorus compounds. They are applied at 5-7 day intervals during the cotton fruiting period to protect the plant from boll weevil and bollworm-budworm damage. Insecticide treatments are initiated in early spring and continue through late summer, thus controlling both the boll weevil and the bollworm-budworm complex.

Diflubenzuron

Diflubenzuron is a specific action insecticide which can be applied to prevent boll weevil reproduction without significantly interfering with natural control provided by the parasites and predators of the bollworm-budworm complex. The efficacy of diflubenzuron against the boll weevil has been demonstrated by researchers who have tested it at many locations through the cotton belt (Coakley, 1976; Lincoln, 1977; Ganyard, 1977).2/

1/ Extensive infestation refers to the geographical extent of pest populations. It does not refer to the intensity of pest infestation (i.e., numbers of pests per square foot).

2/ Appendix III-A summarizes field tests demonstrating the efficacy of diflubenzuron in controlling boll weevil populations and maintaining beneficial insect populations.

Table III-2
Recommended Application Rates of Currently Used Insecticides for Boll Weevil and Bollworm-Budworm Control[a/]

Insecticide	Recommended Application Rate	
	Boll Weevil	Bollworm-Budworm[b/]
	lbs. a.i./acre	
Methyl Parathion	0.25 - 0.5	1.0 - 1.5
Azinphosmethyl	0.25	--
Malathion	0.5 - 1.0	--
EPN + Methyl Parathion	0.25 - 0.5 + 0.25 - 0.05	0.5 - 0.7 + 0.5 - 1.2
Monocrotophos	0.6 - 1.0	0.6 - 1.0
Toxaphene + Methyl Parathion	1.0 + 0.5	1.0 - 4.0 + 0.75 - 1.5
Methomyl	--	0.45 - 0.67

a/ USDA/State/EPA Diflubenzuron Assessment Team for Cotton.
b/ These insecticides may not be effective against resistant tobacco budworms.

Present research findings and expert opinion across the cotton belt indicate that 6 applications of diflubenzuron applied at weekly intervals at the rate of 0.0625 lbs a.i./acre (1 ounce per acre) will effectively reduce boll weevil populations below economically damaging infestation levels.

In addition, diflubenzuron reduces bollworm-budworm control costs because predators and parasites provide mid-season control, delaying the need for insecticide applications. The application of currently used insecticides interferes with the natural predators and parasites of the bollworm-budworm complex, thus allowing rapid increases in the bollworm-budworm population. With the use of diflubenzuron, the beneficial insects are not destroyed and the bollworm-budworm populations are more likely to be maintained at a level below the economic threshold, at least until later in the season. Therefore, the initial treatment specifically for bollworm-budworm can be delayed.

Non-Chemical Control

Various forms of non-chemical control may be used in a cotton pest management program. These measures include: pheromone traps, development and use of early maturing varieties of cotton, non-toxic chemicals, naturally occurring and/or supplemental parasitic and predator controls, release of sterile male insects, viruses and bacteria released to reduce pest populations, and new cropping and tillage techniques. Some of these non-chemical measures are currently used in combination with broad spectrum insecticides. The substitution of diflubenzuron would provide an opportunity for increased usage of these non-chemical pest controls.

ECONOMIC ASSESSMENT

In the economic assessment of diflubenzuron use on cotton, cost-of-control impacts resulting from the substitution of diflubenzuron for currently used insecticides were evaluated at the grower level (user impacts). Cotton production impacts and impacts on cotton consumers were also addressed, but in less detail.

Procedures for Estimating User Impacts

Because diflubenzuron is not registered for use on cotton, critical data on price and market share needed for this analysis were not available. Consequently, the cost-of-control impacts on cotton growers (insecticide users) were estimated by comparing the current insect control costs, from farm budgets prepared under the USDA Firm Enterprise Data System (FEDS), with estimated insect control costs using diflubenzuron.

The analysis addresses the joint insect problem of boll weevil and bollworm-budworm infestation. As described in the "Biological Assessment", diflubenzuron is most useful in areas with both these insect pests, because it controls the boll weevil as effectively as the currently used insecticides and, in addition, contributes to bollworm-budworm control by not interfering with the natural predators of this complex.

In this economic analysis two regimes for the control of boll weevil and the bollworm-budworm complex were compared - one representing the currently used insecticides (currently used insecticides regime) and the second representing a combination of diflubenzuron, natural predators, and currently used insecticides (diflubenzuron regime). The savings in control costs realized by using the diflubenzuron regime were the measure of benefit from using diflubenzuron.

Diflubenzuron Regime - Boll Weevil Control

The boll weevil control portion of the diflubenzuron regime consisted of 6 treatment of 1 ounce of diflubenzuron a.i. applied with 2 quarts of paraffinic oil per acre as described in the "Biological Assessment". A suggested retail price of $3.00 per ounce a.i. was used in this analysis for the diflubenzuron a.i. (Thompson Hayward, 1978). The cost of the paraffinic oil used in the formulation was $0.80 per gallon (2 quarts per acre-treatment). Aerial application costs, presented in Table III-3, varied by state from $1.00 to $1.75 per acre-treatment. The cost of this control, including both materials and application, ranged from $4.40 per acre-treatment to $5.15 per acre-treatment. Treatment costs for the 6 annual treatments for boll weevil control ranged from $26.40 per acre in Alabama to $30.90 per acre in Texas.

The bollworm-budworm control portion of the diflubenzuron regime consisted of the control provided by natural predators left undisturbed by the diflubenzuron treatments, plus late-season application of currently used insecticides. These controls were priced from the FEDS budgets and will be described below in the narrative about Table III-5 and these budgets.

Currently Used Insecticides Regime

The currently used insecticides regime relied on survey data of insect control costs, as reported in the FEDS[1/] budgets. These budgets

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1/ The Firm Enterprise Data System (FEDS) is a system of budgets and cost-estimating procedures operated by ESCS, USDA research staff stationed at Oklahoma State University. This system is used to provide annually updated production cost estimates between years when farmers are surveyed and to provide production cost projections for the upcoming crop year. Based on 1974 farm production practices, 194 budgets for 10 crops have been prepared with this system.

Table III-3

Cost of Aerial Application[a/]

Region and State	Application Cost 1.00	1.10	1.25	1.50	1.75
	----------dollars per acre----------				
Southeast					
Alabama	X				
Georgia				X	
North Carolina				X	
South Carolina		X			
Delta					
Arkansas			X		
Louisiana			X		
Mississippi				X	
Missouri				X	
Tennessee				X	
Southwest					
Oklahoma				X	
Texas					X

a/ Entomologists cooperating with USDA/State/EPA Diflubenzuron Assessment Team

represented average costs of controlling all cotton insects per acre with currently used insecticides.

The average boll weevil control cost with the currently used insecticides, including materials and application cost, was estimated to be $3.00 per acre-treatment (Lloyd, 1978). This is somewhat lower than the $4.40-$5.15 per acre-treatment cost of using diflubenzuron. Because of the relatively high cost of diflubenzuron as a boll weevil suppression material, it was assumed that this insecticide could only be used in an economically efficient manner on acreage requiring high rates of insecticide application. Based on this assumption, diflubenzuron would only be used on acreage with current insect control costs exceeding $45.00 per acre.

These two criteria - (1) areas with both boll weevil and bollworm-budworm infestations, and (2) insect control costs exceeding $45.00 per acre - identified 11 FEDS areas (Table III-4) where diflubenzuron might be used on about 1.5 million acres (Table III-5).

Table III-5 shows the total insect control costs per acre for each of the FEDS areas (Column 1) in the analysis, the costs of the currently used insecticides regime (Column 4), and the cost of bollworm-budworm control in the diflubenzuron regime (Column 7). In addition, it shows the difference in control costs between the two regimes on both a per acre and aggregate basis. The following paragraphs will describe each calculation. Appendix III-B contains an example of these calculations using FEDS area 400 in Georgia.

Table III-4

Insect Control Costs by Firm Enterprise Data System Areas, 1977[a/]

Region and State	FEDS Area	Acreage in Area	Yield	Insect Control Costs: Insecticide Cost	Insect Control Costs: Application Cost	Insect Control Costs: Total	Total Variable Cost	Insect Control As a Percent Of Variable Cost
		1,000 acres	lbs/acre	dollars/acre				percent
Southeast								
Alabama	100-200	81.1	407.8	42.24	8.59	50.84	220.69	23
	500	67.0	401.9	34.60	6.87	48.24	216.41	22
	600	244.9	361.2	34.60	4.81	39.41	189.09	21
Georgia	400	75.7	515.2	73.68	18.57	92.24	275.29	34
	500	57.3	409.2	62.55	18.34	80.89	252.91	32
North Carolina	All	56.0	390.0	68.78	16.97	85.75	238.69	36
South Carolina	100	47.4	459.9	54.73	—	54.73	222.67	25
	200	45.7	476.5	67.58	34.39	101.97	262.42	39
Delta								
Arkansas	200	276.0	440.0	16.02	14.87	30.89	156.01	20
	300	383.6	489.0	21.87	2.29	24.17	162.00	15
Lousiana	100	289.0	512.0	50.53	14.38	65.00	218.13	23
Mississippi	100	712.5	443.0	50.33	18.00	68.29	215.39	32
	200	250.9	463.0	14.03	14.38	28.75	215.32	13
	300	45.2	280.0	25.33	13.24	38.58	168.65	23
Missouri	400	220.0	429.0	2.00	0.12	2.12	134.19	2
Tennessee	100	302.8	390.3	9.63	b/	9.63	151.68	6
Southwest								
Oklahoma	300	269.7	208.0	0.11	0.46	0.57	69.58	0.8
	300	50.0	386.3	1.58	6.81	8.39	152.23	5.5
Texas	200	1,160.5	228.0	1.17	0.14	1.31	64.78	2
	200	1,420.4	262.8	0.45	23.06	0.58	105.12	0.5
	300	912.5	227.9	0.42	0.46	0.88	61.00	1
	300	80.0	367.0	1.56	1.42	2.98	140.79	2
	400	76.3	254.8	0.44	0.44	0.87	69.23	1
	600	55.5	377.3	31.72	14.90	46.62	159.99	29
	600	55.9	456.1	41.05	18.34	59.40	236.90	25
	900	384.9	184.0	7.58	1.72	9.30	72.05	13
	1,000	104.8	442.3	19.90	6.42	26.31	147.05	18

a/ USDA, ERS. Firm Enterprise Data System. Prepared in cooperation with Oklahoma State University, 1975.
b/ No custom application reported by FEDS, 1975.

Table III-5

Representative Boll Weevil and Bollworm-Budworm (Heliothis) Control Costs for Currently Used Insecticides Regime and Diflubenzuron Regime, by FEDS Area, 1977[a]

on and te	FEDS Area	Acreage in Area	Control Costs with Currently Used Insecticides[d]			Value of Natural Predators[e]	Residual Heliothis Control Cost[f]	Cost of Difluben-zuron Regime[g]	Savings from Use of Diflubenzuron Regime		
			All Insects[b]	Boll Weevil and Heliothis[c]	Heliothis				Per Acre[h]	Feasible Acreage	Aggregate
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		1,000 acres	----	----	----	dollars/acre	----	----	----	1,000 acres	$1,000
heast											
abama	100-200	81.1	50.84	41.94	23.94	7.66	16.28	42.68	0	—	0
	500	67.0	48.24	39.80	21.80	6.98	14.82	41.22	0	--	0
orgia	400	75.7	92.24	90.12	60.12	18.04	42.08	71.48	18.64	75.7	1,411.0
	500	57.3	80.89	79.03	49.03	14.71	34.32	63.72	15.31	57.3	877.3
rth Carolina	all	56.0	85.74	61.74	41.74	21.74	20.00	49.40	12.34	56.0	691.0
uth Carolina	100	47.4	54.73	49.80	28.80	1.15	27.65	54.65	0	—	0
	200	45.7	101.97	92.79	71.79	2.87	68.92	95.95	0	—	0
Total		430.2								189.0	2,979.3
ta											
uisiana	100	289.0	65.00	58.18	43.18	16.41	26.77	54.67	3.51	289.0	1,014.4
ississippi	100	712.5	68.29	62.14	47.14	22.16	24.98	54.38	7.76	712.5	5,529.0
Total		1,001.5								1,001.5	6,543.4
thwest											
exas	600	55.5	46.62	41.96	17.96	10.78	7.18	38.08	3.88	55.5	215.3
	600	55.9	59.40	53.46	29.46	17.68	11.78	38.78	14.68	55.9	820.6
Total		111.4								111.4	1,030.0
										1,301.9	10,558.7
AL		1,543.1									

USDA, ERS, Firm Enterprise Data System, prepared in cooperation with Oklahoma State University, Stillwater Oklahoma, 1975.
All costs have been inflated to 1977 price level.
Includes spidermites, thrips, leaf hoppers, etc. in addition to boll weevil and bollworm-budworm.
Cost of currently used insecticides regime. Calculated by subtracting control costs for all insects except boll weevil and bollworm-budworm from Column 3. These costs estimated by USDA/State/EPA Diflubenzuron Assessment Team for Cotton.
Column 4 minus boll weevil control costs, ($3.00 per acre-treatment).
Estimated by USDA/State/EPA Diflubenzuron Assessment Team for Cotton
Column 5 minus Column 6.
Column 7 plus the cost of diflubenzuron for control of boll weevil (6 applications times cost of material ($3.40 per application) and application (Table III-3)).
Column 4 minus Column 8.

Column 3, the "Total Insect Control Cost per Acre", is the cost of controlling all cotton insects in individual or multiple FEDS areas with currently used insectcides. The most recent FEDS budgets available, containing 1975 data were used in this analysis. These data were adjusted to the 1977 price level using a composite inflator of 14 leading economic indicators (USDA, 1978a). The cost of controlling spider mites, trips, leaf hoppers and other insect pests of cotton which are not susceptible to diflubenzuron, in addition to boll weevil and the bollworm-budworm complex, are included in these total costs.

Column 4 contains the control costs for boll weevil and the bollworm-budworm complex for the currently used insecticides regime. These numbers were calculated by subtracting the costs of controlling insects not susceptible to diflubenzuron from the total control costs. To estimated these control costs, the USDA/State/EPA Diflubenzuron Assessment Team for Cotton estimated the number of acre-treatments and multiplied this percentage by the total insect control cost per acre for each FEDS area. These non-affected insect control costs were subtracted from the total costs to calculate the control cost for boll weevil and bollworm-budworm using current insecticides.

Diflubenzuron Regime - Bollworm-Budworm Control

Columns 5 to 7 display the results of estimating the cost of controlling the bollworm-budworm complex in the diflubenzuron regime. Column 5 is an intermediate step showing the control costs for the bollworm-budworm complex with currently used insecticides. These costs were calculated by subtracting boll weevil control costs from the costs of currently used insecticides from Column 4. These boll weevil

control costs were estimated by multiplying the average cost of $3.00 per application by the number of applications per year, provided to the Assessment Team by cooperating entomologists in the states affected (see Appendix III-C).

The value of natural predators in controlling the bollworm-budworm complex (Column 6) was estimated by the Assessment Team utilizing information from cooperating entomologists familiar with research on natural predators. The evaluation compared the number of acre-treatments with the currently used insecticides regime necessary to control the bollworm-budworm complex with the number of acre-treatments of diflubenzuron regime (see Table III-6). The percentage change in acre-treatments from the currently used insecticides regime to the diflubenzuron regime was multiplied by the cost of bollworm-budworm control with currently used insecticides (Column 5 in Table III-5) to obtain the value of natural predators.

Column 7 shows the cost of late-season control of the bollworm-budworm complex in the diflubenzuron regime using current insecticides. It was calculated by subtracting the value of natural predator control (Column 6) from the current control cost (Column 5).

The total costs of the diflubenzuron regime are tabulated in Column 8. These figures are the sum of the boll weevil control costs using diflubenzuron and the bollworm/budworm control costs from Column 7.

Cost-of-Control Savings

The difference between the two control regimes (Column 4 minus Column 8) is tabulated in Column 9. If this difference is negative, i.e., the diflubenzuron regime is more costly than the currently used

Table III-6

Number of Acre-Treatments for Bollworm/Budworm Control Corresponding with Current Practice and Diflubenzuron Use to Control Boll Weevil[a/]

and State	Acre-Treatment for Bollworm/Budworm Control								Change in Number of Acre Treatments For Control	Percent Change from Current Practice
	Current Practice				Diflubenzuron					
	Light	Moderate	Extensive	Weighted Average	Light	Moderate	Extensive	Weighted Average		
	thousand acre-treatments									Percent
ast										
labama	3,205	3,822	3,894	3,782	2,174	2,599	2,643	2,570	-1,212	32
eorgia	1,644	3,861	4,304	3,329	1,083	2,721	3,056	2,330	- 999	30
orth Carolina	103	870	870	793	79	692	692	631	- 162	20
outh Carolina	2,034	2,277	2,277	2,253	1,684	2,208	2,208	2,156	- 97	4
Total	—	—	--	10,157	--	—	--	7,637	-2,470	24
rkansas	1,032	2,065	4,827	2,342	586	1,179	2,753	1,335	-1,007	43
ouisiana	1,828	2,757	2,757	2,571	1,138	1,721	1,721	1,604	- 967	38
ississippi	976	2,439	4,789	2,998	425	1,588	1,970	1,586	-1,412	47
issouri	—	--	202	20	--	—	164	16	- 4	20
ennessee	—	1,523	2,284	1,370	--	645	964	579	- 791	58
otal	—	—	--	9,301	--	—	—	5,120	-4,181	45
est										
klahoma	342	836	1,520	943	147	364	658	409	- 534	57
exas:										
Region 2	782	1,045	1,571	1,111	38	51	76	54	-1,057	95
Region 3	413	1,565	1,627	1,475	92	343	363	326	-1,149	78
Region 4	77	79	82	80	48	50	52	50	- 30	50
Region 5	2,039	2,133	2,290	2,174	601	628	651	632	-1,542	71
Region 6	203	265	360	262	104	120	183	127	- 135	52
Region 7	202	236	295	250	112	135	165	142	- 108	43
otal 6 Texas otton Regions	—	--	—	6,295	--	--	—	1,740	-4,555	72
	—	--	--	25,753	--	—	--	14,547	-11,206	44

stimated by USDA/State/EPA Diflubenzuron Assessment Team for Cotton

insecticides regime, a zero is entered in the column. In FEDS areas where this occurs it was assumed that diflubenzuron would not replace the currently use insecticides.

Only those areas with savings from the diflubenzuron regime were considered likely to use diflubenzuron. Since each area was assumed to be homogeneous, all of the acreage in an area was assumed to be converted to diflubenzuron if any was. This acreage was termed "feasible acreage" (Column 10).

Aggregate savings in cost of control (Column 9 multiplied by Column 10) from adopting the diflubenzuron regime are tabulated in Column 11.

Key Assumptions and Limitations

1. A proposed boll weevil treatment schedule for diflubenzuron of 6 applications of 1 ounce per acre was used for purposes of analysis. The proposed label does not restrict the amount applied to 6 ounces per year. If the amount of diflubenzuron applied in a season differed from 6 ounces, the results of this analysis would change.
2. Diflubenzuron is not registered and has not been marketed for use on cotton. Consequently, data critical to this analysis, such as retail price of diflubenzuron and acres treated, were not available.

   A manufacturer suggested retail price for diflubenzuron of \$3.00 per ounce active ingredient was used in the anlaysis. Acreage treated was estimated from a series of calculations based on subjective estimates of entomologists in affected states.
3. The FEDS budgets were assumed to represent costs for controlling all insect pests of cotton with currently used insecticdes in an average infestation year. It was also assumed that those areas selected as feasible for adoption of the diflubenzuron regime, i.e.,

those areas with total insect control costs exeeding $45.00 per acre, had a serious bollworm-budworm infestation. In addition, it was assumed that natural predators could control a bollworm-budworm infestation for a sufficiently long period of time to reduce the number of insecticide applications to control this worm complex.

User Impacts

Cost-of-Control Savings

The analysis identified 1.3 million acres where the diflubenzuron regime for suppression of boll weevil and control of the bollworm-budworm complex would be used because it was more cost efficient than the currently used insecticides regime (Table III-5, Column 10). The 1.3 million acres is approximately 18 percent of the total boll weevil infested cotton acreage. The percentage of total cotton production acreage identified for diflubenzuron use in each region is: 18 percent in the Southeast, 27 percent in the Delta, and 2 percent in the Southwest.

The total decrease in insect control costs for all regions is $10.6 million. The Delta accounted for most of this total with approximately $6.5 million, followed by the Southeast with $3.0 million and the Southwest with $1.0 million. The weighted average savings per acre was $7.80. The regional average cost savings per acre were $15.76, $6.53, and $9.25 for the Southeast, Delta, and Southwest regions, respectively. The FEDS area with the largest cost savings per acre, $18.64, was in Georgia, while the area with the highest aggregate savings, $5.5 million, was in Mississippi.

The value of natural predators ranged from $1.15 per acre in South Carolina to $22.16 per acre in Mississippi. This value represents the cost of the displaced insecticide treatments for bollworm-budworm control.

Change in Production Value

No yield effects were associated with adoption of the diflubenzuron regime. Consequently, there was no change in the value of production in this analysis.

However, it was the consensus of the cooperating entomologists that cotton yields would increase because of 1) a reduction in the amount of organophosphorus insecticides resulting in earlier plant maturity and 2) greater control of resistant varieties of tobacco budworm by beneficial insects.

If a yield increase of 5 percent were realized on the 1.3 million acres that could be treated with diflubenzuron, approximately 29.7 million pounds of additional cotton could be produced. Gross revenue from these acres would increase $15.6 million annually. This increased output would probably depress market prices, _ceteris paribus_, but these price reductions would be minimal (see Appendix III-D).

Consumer and Social Impacts

Consumer impacts were not estimated. If the entomologists are correct and there are some yield effects from adopting the diflubenzuron regime, it is expected that the effect on cotton production would still be too small to affect price or availability at the consumer level.

However, there may be some social impacts from the use of diflubenzuron, since it has been estimated that 488,000 pounds of diflubenzuron would replace 5.6 million pounds of boll weevil suppression materials and 8.3 million pounds of bollworm-budworm suppression materials annually (see Appendix III-E).

Use of Diflubenzuron in the Boll Weevil Eradication Program

Background

The Federal government in cooperation with the states, currently is investigating the technical and economic feasibility of instituting a beltwide boll weevil eradication program. The activity is being initiated with a trial eradication program for a selected area in North Carolina. The agency within the USDA responsible for managing the trial eradication is the Animal Health and Plant Inspection Service (APHIS). However other USDA Agencies including SEA and ESCS and the state experiment station and extension services are involved in biologic and economic monitoring and evaluation to assess the overall biologic and economic feasibility. If there is a beltwide eradication program it is expected that it will be initiated in the east and gradually extend to other contiguous infested areas.

The purpose of this report is to appraise two alternative control regimes proposed for use in the eradication effort. One regime utilizes conventional insecticides currently in use, and the other regime utilizes conventional insecticides and a chiton-inhibitor, diflubenzuron, not presently registered for boll weevil suppression.

The eradication technology employs the integration of chemical, biological, and cultural control measures. The eradication trial strategy currently contains provisions for the following elements.

1. Inseason control with insecticides
2. Late season reproduction-diapause control involving:
   a. Insecticides to reduce over wintering populations, and

b. Destruction of food by defoliation and stalk destruction

3. Pheromone traps

4. Release of sterile boll weevils

Diflubenzuron has been proposed to augment the present eradication strategy. Its advantage is that it's specific mode of action does not interfere with the sterile release component of the eradication, since it does not kill mature adults, but does cause eggs to be infertile and thus prevents subsequent generations. At the same time, it helps prevent a flair-up in the bollworm - budworm problem because the natural enemies of the bollworm - budworm, are not eliminated as they are with the use of conventional insecticides.

Comparison of Potential Beltwide Eradication Program Options

Expenditures and finance estimates for the two program options are based on a representative per acre cost and are expanded by the 1974-76 average cotton acreage in three cotton producing regions.

a. Preliminary Year

Both alternative eradication programs would include normal overhead and/or start up expenditures such as building, transportation, and personnel costs. These costs would be incurred for both programs and are included in first year operational expenditures.

b. First Year

The proposed activities of the first year programs are distinctly different. The major difference between the two alternatives is the intense area-wide conventional chemical control required the first year to suppress boll weevil populations if diflubenzuron is not

available. The operational activities of the first year without diflubenzuron include complete insect control and application of harvest aid chemicals (the last item being optional at grower's digression) to be performed by USDA/APHIS. The chemical control materials used would be similar to current cotton insect control practices (i.e., boll weevil-malathion and guthion, and bollworm/ budworm-EPN plus methyl parathion and toxaphene plus methyl parathion). The total expected average number of insecticide applications is dependent upon existing pest pressures (i.e., the estimated number of applications for South Carolina is 11-15 applications). The financing of the expenditures is a 50% - 50% grower and state and federal government agency cooperative effort.

The first year of the alternative with diflubenzuron would be a monitor year for the program concentrating on infestation surveys. The monitor effort would consist of traps and cooperation from existing management and survey programs conducted by the USDA Extension Service. Also, ideally pest management education programs would be conducted at the same time. These activities are not considered in the USDA/ APHIS operating budget. A monitor effort would be designed to pinpoint areas of heavy boll weevil infestation with recommendations made to the grower for voluntary diapause treatment.

A comparison of the first program years expenditures illustrates the major cost savings achieved by the use of diflubenzuron. Since the first year with difulbenzuron does not rely on mandatory applications of conventional insecticides, there is a saving in program costs. These savings in expenditures for materials are inpart offset by the cost of diflubenzuron in the second program year. However, further

savings are realized in this year by fewer personnel and overhead costs necessary for the enactment of the mandatory all season insecticide applications necessary without diflubenzuron. This savings is approximately $8 million or 50% of the total change in cost (see summary table).

c. Second Year

The without diflubenzuron program would treat with current chemical controls for boll weevils at the pinhead square stage of the cotton plant. Sterile male boll weevils would then be released. In-season chemical controls would be used only for heavy population areas in late stages of the growing season for both alternatives. The with diflubenzuron second year initiates the control measures of diflubenzuron use and sterile releases. The personnel and overhead costs are similar to the first year with diflubenzuron program.

d. Third Year

The third year is a monitor year for both programs. There would be some chemical or diflubenzuron treatments for any areas with remaining infestations. However there would be no extensive in-season boll weevil treatments. Sterile insect releases would continue. Personnel and overhead costs are similar.

e. Summary

The distinguishing difference between programs is that the use of diflubenzuron would reduce the major operational activities of suppression to two years where, without diflubenzuron, the operational activities are in effect for three years. The most notable cost differences between programs are reduced personnel years and one less

year of building and transportation costs.

Comparative Expenditures and Financing

The regional and summary tables itemize the types of expenditures include in the boll weevil eradication program. A major cost difference between the regimes is the operation of the first program year. The cost per acre of a government operated insect control program for the first year is $61.00.

The government insect control program would not be necessary if diflubenzuron is used, however, a voluntary reproduction diapause control program to be initiated by the grower would be an additional $11.00 to $20.00 per acre, but is not part of the joint finance agreement. The savings to the operating expenditures are in terms of chemical controls not used and in the personal and overhead necessary to supervise and apply them. The personal and overhead savings are $15 million, $36 million, and $16 million for the Southeast, Mid-South, and Southwest, respectively. This cost difference is reflected in the disproportionate finance costs for the state and federal government and grower in the first program year. The total savings in expenditure by using diflubenzuron is $161.1 million. The savings accruing to the state and federal government is $115.6 million and $45.5 million to the growers.

Table III - 7

Comparative expenditures and financing of two alternative boll weevil eradication programs, by item Southeast area region and acreage

Item	Without diflubenzuron				With diflubenzuron 1/			
	1st year	2nd year	3rd year	Total	1st year	2nd year	3rd year	Total
	Thousand dollars							
EXPENDITURES								
Control agents								
Chemical control 2/	73,091	12,000	3,000	88,091	14,618 5/	7,309	-	21,927
Diflubenzuron 2/						26,070	13,035	39,105
Sterile insects	-	15,273	1,636	16,909		15,273	1,636	16,909
Insect pest monitors								
Traps	1,854	4,364	4,364	10,582	873	4,364	4,364	9,601
Operational costs 3/	1,636	1,636	1,636	4,908	327	1,636	1,636	3,599
Sub-total	76,581	33,273	10,636	120,490	15,818	54,652	20,671	91,141
Personnel and Overhead								
Field, research and support staff	14,727	10,909	10,909	36,545	1,091	14,727	10,909	26,727
Supervision	2,182	2,182	2,182	6,546	545	2,182	2,182	4,909
Cotton measures	1,091	545	545	2,181		1,091	545	1,636
Building and transportation overhead	3,818	3,818	3,818	11,454	764	3,818	3,818	8,400
Sub-total	21,818	17,454	17,454	56,726	2,400	21,818	17,454	41,762
TOTAL PROGRAM EXPENDITURES	98,399	50,727	28,090	177,216	18,218	76,470	38,125	132,813
FINANCING 4/								
Grower participation	49,200	25,364	14,545	88,608	15,818 5/	38,235	19,062	73,115
Government	49,200	25,364	14,545	88,608	2,400	38,235	19,062	59,697

Table III - 9

Comparative expenditures and financing of two alternative boll weevil eradication programs, by item Southwest region

Item	Without diflubenzuron				With diflubenzuron 1/			
	1st year	2nd year	3rd year	Total	1st year	2nd year	3rd year	Total
	Thousand dollars							
EXPENDITURES								
Control agents								
Chemical control 2/	97,990	16,090	7,150	121,230	19,598 5/	9,799	-	29,397
Diflubenzuron 2/						61,620	30,810	92,430
Sterile insects	-	36,400	3,900	40,300		36,400	3,900	40,300
Insect pest monitors								
Traps	4,420	10,400	10,400	25,220	2,080	10,400	10,400	22,880
Operational costs 3/	1,651	1,651	1,651	4,953	384	1,651	1,651	3,868
Sub-total	104,061	64,541	23,101	191,763	22,062	119,870	46,761	188,876
Personnel and Overhead								
Field, research and support staff	23,530	17,650	18,650	58,830	1,765	23,530	17,650	42,945
Supervision	3,900	3,900	3,900	11,700	975	3,900	3,900	8,775
Cotton measures	2,600	1,300	1,300	5,200		2,600	1,300	3,900
Building and transportation overhead	7,059	7,059	7,059	21,177	1,394	7,059	7,059	15,512
Sub-total	37,089	29,909	29,909	96,907	4,134	36,998	29,818	70,950
TOTAL PROGRAM EXPENDITURES	141,150	94,450	53,101	288,610	26,196	156,959	76,670	259,825
FINANCING 4/								
Grower participation	70,575	47,225	26,508	144,305	22,897	78,480	38,335	139,711
Government	70,575	47,255	26,505	144,305	3,299	78,480	30,335	120,114

Table III - 8

Comparative expenditures and financing of two alternative boll weevil eradication programs, by item Mid-South region and acreage

Item	Without diflubenzuron				With diflubenzuron 1/			
	1st year	2nd year	3rd year	Total	1st year	2nd year	3rd year	Total
	Thousand dollars							
EXPENDITURES								
Control agents								
Chemical control 2/	185,387	30,441	10,193	226,021	37,077	18,538	-	55,615
Diflubenzuron 2/					-	87,690	43,845	131,535
Sterile insects	-	51,649	5,534	57,183		51,649	5,481	57,130
Insect pest monitors								
Traps	6,272	14,757	14,757	35,768	2,951	14,758	14,758	32,467
Operational costs 3/	12,364	12,364	12,364	37,092	2,473	12,354	12,354	27,181
Sub-total	204,023	109,211	42,848	356,082	42,501	184,989	76,438	303,928
Personnel and Overhead								
Field, research and support staff	33,392	25,055	25,055	83,502	2,530	33,392	25,055	60,977
Supervision	5,534	5,534	5,534	16,602	1,054	5,534	5,534	12,122
Cotton measures	3,689	1,845	1,845	7,379	1,054	3,689	1,845	5,534
Building and transportation overhead	8,675	8,675	8,675	26,025	1,735	8,675	8,675	19,085
Sub-total	51,290	41,109	41,109	133,508	5,319	51,290	41,109	97,718
TOTAL PROGRAM EXPENDITURES	255,313	150,320	83,957	489,590	47,820	236,279	117,547	401,646
FINANCING 4/								
Grower participation	127,656	75,160	41,978	244,795	42,448	118,140	58,774	219,362
Government	127,656	75,160	41,978	244,795	5,392	118,140	58,774	182,286

Areas

Southeast included: North Carolina, South Carolina, Georgia, and Alabama. The average (1974-1976) acreage is estimated to be 1.1 million acres.

Mid-South included: Missouri, Tennessee, Arkansas, Mississippi, and Louisiana. The average (1974-1976) acreage is 3.7 million acres.

Southwest included; Oklahoma and Texas. The average (1974-1976) acreage is 2.6 million acres.

1/ Diflubenzuron is presently under study by the EPA for a request for registration (7-17-78)
2/ Includes materials and cost of application for six treatments per acre. $2.55/tr/ac diflubenzuron, $0.40/tr/ac. paraffinic oil, and $1.00/tr/ac. for application
3/ Includes gasoline, storage of traps, trap lure and maintenance.
4/ The financing of the program is a cooperative effort between the USDA and the cotton growers. There are some activities in the first year where monitored high insect populations may be treated voluntarily by the grower (this is part of the grower's control practices and not part of the operational expenditures for the program.)
5/ The first year with diflubenzuron requires less restrictive pest management than without diflubenzuron. The first year, in this case, would rely on the grower's current control practices and some voluntary diapause treatments rather than in institutionally operated areawide pest management program. Because of the concurrence of the insect pest, Heliothis, not all grower treatments are solely for boll weevil suppression. These costs may be overstated.

Table III - 10

Comparative expenditures for two alternative boll weevil eradication programs

Summary Table

Region	Acres treated	Without Diflubenzuron	With Diflubenzuron	Change in cost
	Million acres	- - - - - - - - - -	dollars	- - - - - - - - - -
Southwest	1.1			
Total (000)		177,216	132,813	44,403
Per acre		161.	121.	40.
Mid-South	3.7			
Total (000)		489,590	401,646	87,944
Per acre		132.	108.	24.
Southwest	2.6			
Total (000)		288,610	259,826	28,784
Per acre		111.	99.	11.
U.S. Total	7.4			
Total (000)		955,416	794,285	161,131
Per acre		129	107	22.

Appendix III-E

Estimated Substitution and Displacement of Current Control Regime Insecticide Materials by a Diflubenzuron Regime for Suppression of Boll Weevil and Bollworm - Budworm on Expected Use Acreage

The use of insecticides on cotton is of concern to growers in attempting to minimize the costs of production and to the public for health and environmental reasons. Diflubenzuron use based on existing data and expert opinion may serve as a substitute for existing boll weevil suppression materials. Also, diflubenzuron affects only the boll weevil and not the natural enemies of the bollworm - budworm complete therefore, natural enemies are maintained. The maintenance of these natural enemies should delay the beginning of the control schedule for bollworm/budworm thus, displacing a few costly and intense insecticide treatments.

Table III-E contains estimates of the quantity of current, popular materials that would be substituted for and displaced by a diflubenzuron regime. The distribution of materials is from the 1976 National Pesticide Survey (preliminary USDA data) and is considered homogeneous across the regions for purposes of this analysis. The conventional insecticide materials listed are not exact substitutes in all cases (often user preference, atomospheric, and agronomic conditions dictate the choice of materials). The number of acre-treatments and the rates of application are from the USDA/State/EPA Diflubenzuron Assessment Team. The quantity of diflubenzuron used is calculated from the proposed total rate scheduling of 6 ounces per acre year.

An estimated total of 13.3 mil. pounds of chemicals would be displaced by a diflubenzuron regime. Of this amount about 5.6 mil. pounds of boll weevil suppression materials would be substituted for .5 mil. pounds of diflubenzuron on acreage that could be treated with diflubenzuron and 8.2 mil. pounds of bollworm - budworm materials would be displaced by actions of the natural enemies. The average net decrease in insecticides applied per acre is 6.4 pounds.

Appendix table III-E

—Estimated substitution and displacement of current control regime insecticide materials by a diflubenzuron regime for suppression of boll weevils and bollworm/budworm on most feasible acreage. 1/

Quantity of current materials substituted for boll weevil suppression 2/

Region	Acres	Toxaphene	Methyl parathion	Azinphos-methyl	Other	Total
	Thous. acres	- - - - Thousand pounds active ingredients - - - - - - - -				
Southeast	189	430.7	870.1	107.7	35.9	1,444.4
Delta	1,001	1,501.5	1,501.5	375.4	125.1	3,503.6
Southwest	111	266.4	266.4	66.6	22.2	621.6
Total	1,301	2,198.6	2,638.0	549.7	183.2	5,569.6

Quantity of current materials displaced for bollworm/budworm control 2/

Region	Acres	Toxaphene	EPN	Methyl parathion	Mono crotophos	Other	Total
	Thous. acres	- - - - - - - - - Thousand pounds active ingredients - - - - - - - - -					
Southeast	189	484.6	72.7	315.0	24.2	72.7	969.2
Delta	1,001	3,224.0	483.6	2,095.6	161.2	483.6	6,448.0
Southwest	111	423.8	63.6	275.5	21.2	63.6	847.7
Total	1,301	4,132.4	619.9	2,586.1	206.6	619.9	8,264.9

Estimated total diflubenzuron use and the substitution or displacement of current materials

Region	Total estimated diflubenzuron use	Total substituted or displaced current materials	Net change in quantity
	Thousand pounds active ingredients		
Southeast	70.9	2,413.6	- 2,342.7
Delta	375.4	9,951.6	- 9,576.2
Southwest	41.6	1,469.3	- 1,427.7
Total	487.9	13,834.5	- 13,346.6

1/ Diflubenauron substitutes for boll weevil suppression materials and displaces some bollworm/budworm controls by noninterference with natural enemies. Table III-5 for example of most feasible acreage. The price of diflubenzuron is assumed to be $5 per once.

2/ Major control materials were identified by the Federal/State Dimilin Assessment Team. They are assumed to be distributed homogeneously throughout the United States. New insecticides such as synthetic pyrethroids are not included because of limited commercial use. The data are from USDA/ESCS, 1976 National Pesticide Use Survey.

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IV. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON ON SOYBEANS

IV. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZURON ON SOYBEANS[1/]

INTRODUCTION

The major U.S. soybean production area extends from the North Central region to the mid-Atlantic region and south to the Southeast and Delta regions. For the period 1975-1977, 54 million acres of soybeans were harvested annually with production averaging 1.5 billion bushels (Table IV-1). The North Central region is the most important soybean production area in the U.S. It accounts for 62 percent of the acreage and 69 percent of the soybean production. The North Central region has the highest average yield at 31.4 bushels per acre. The average yield in the other regions is about 25 bushels per acre or less, with the lowest average yield being registered in the Southeast at 22.1 bushels per acre (Table IV-1).

A relatively small, although increasing, proportion of soybean acreage has been treated with insecticides. In 1966, 4 percent of the soybean acreage was treated with insecticides, 8 percent in 1971 and 10 percent in 1976 (USDA, 1975, 1976).

Historically, the major insecticides used on soybeans for all insect pests have been carbaryl, methyl parathion and toxaphene (Table IV-2). Carbaryl has shown the greatest growth in usage between 1971 and 1976, increasing from 1.3 million pounds and 0.9 million acres treated in

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1/ Prepared by those members of the Joint USDA/State/EPA Diflubenzuron Assessment Team assigned to the evaluation of potential diflubenzuron use on soybeans. This group of people, referred to in this report as the "Diflubenzuron Soybean Assessment Team" consisted of the following individuals: Merle Shepard, Ph.D., Clemson University; Donald C. Herzog, Ph.D, University of Florida; Herman W. Delvo, Ph.D., USDA; Robert E. Lee, II, Ph.D., EPA; and received assistance from a variety of people, most extensively from Galen P. Dively, Ph.D., University of Maryland; Larry P. Pedigo, Ph.D., Iowa State University; George F. Ludvik, Ph.D., EPA; and Craig Tinney, USDA.

Table IV-1

Soybeans: Average Area Harvested, Production and Yield Per Acre by State and Region, 1975-1977[a/]

Region & State	Area Harvested	Production	Yield Per Harvested Acre
	1,000 acres	mil. bushels	bushels
Northeast			
New York	12	.3	25.0
New Jersey	139	3.3	23.7
Pennsylvania	56	1.6	28.6
Total	207	5.2	25.1
Mid-Atlantic			
Delaware	218	5.2	25.0
Maryland	315	8.3	26.3
Virginia	420	9.0	21.4
North Carolina	1,287	29.0	22.5
Total	2,240	51.5	23.0
Southeast			
South Carolina	1,290	25.9	20.1
Georgia	1,040	23.9	23.0
Florida	287	7.1	24.7
Alabama	1,343	30.8	22.9
Total	3,960	87.7	22.1
Delta			
Arkansas	4,540	100.3	22.1
Louisiana	2,283	58.0	25.4
Mississippi	3,340	72.2	21.6
Tennessee	1,950	45.8	23.5
Kentucky	1,177	32.9	28.0
Total	13,290	309.2	23.3
Southern Plains			
Oklahoma	254	5.6	22.0
Texas	492	12.7	25.8
Total	746	18.3	24.5
North Central			
Ohio	3,120	104.6	33.5
Indiana	3,593	124.1	34.5
Illinois	8,243	292.4	35.5
Missouri	4,557	113.9	25.0
Iowa	6,883	227.6	33.1
Michigan	632	16.1	25.5
Wisconsin	184	5.0	27.2
Minnesota	3,493	99.4	28.5
North Dakota	162	2.8	17.3
South Dakota	306	7.4	24.2
Nebraska	1,120	30.7	27.4
Kansas	978	21.1	21.6
Total	33,271	1,045.1	31.4
U.S. Total	53,714	1,517.0	28.2

a/ USDA, ESCS, Crop Production-1977, Annual Summary, CrPr 2-1(78), Washington, D.C., January 1978

Table IV-2

Quantity of Currently Used Insecticides
to Control Pests of Soybeans,
1971 and 1976

Insecticide	1971[a/]	1976[b/]
	1,000 pounds	
Carbaryl	1,346	3,668
Methomyl	--[c/]	483
Malathion	89	--
Methyl Parathion	2,209	713
Toxaphene	1,524	2,206
	1,000 acres	
Carbaryl	913	2,923
Methomyl	--	865
Malathion	110	--
Methyl Parathion	2,150	677
Toxaphene	951	488

a/ USDA, ERS, Farmers' Use of Pesticides in 1971 - Quantities, AER No. 252, July 1974.
b/ USDA, ESCS, "1976 National Pesticide Usage Survey," unpublished.
c/ No use reported.

1971 (USDA, 1974) to 3.7 million pounds and 2.9 million acres treated in 1976 (USDA, 1976). Methyl parathion was used in the largest quantity, 2.2 million pounds, and on the largest acreage, 2.2 million acres in 1971 (USDA, 1974), but by 1976, usage of this insecticide had dropped to 0.7 million pounds and 0.7 million acres (USDA, 1976). The quantity of toxaphene used increased from 1.5 million pounds in 1971 to 2.2 million pounds in 1976, but the acreage treated declined from 1.0 million acres to 0.5 million acres. However, in 1976, much of the toxaphene treated acreage received 2-3 applications during the season.

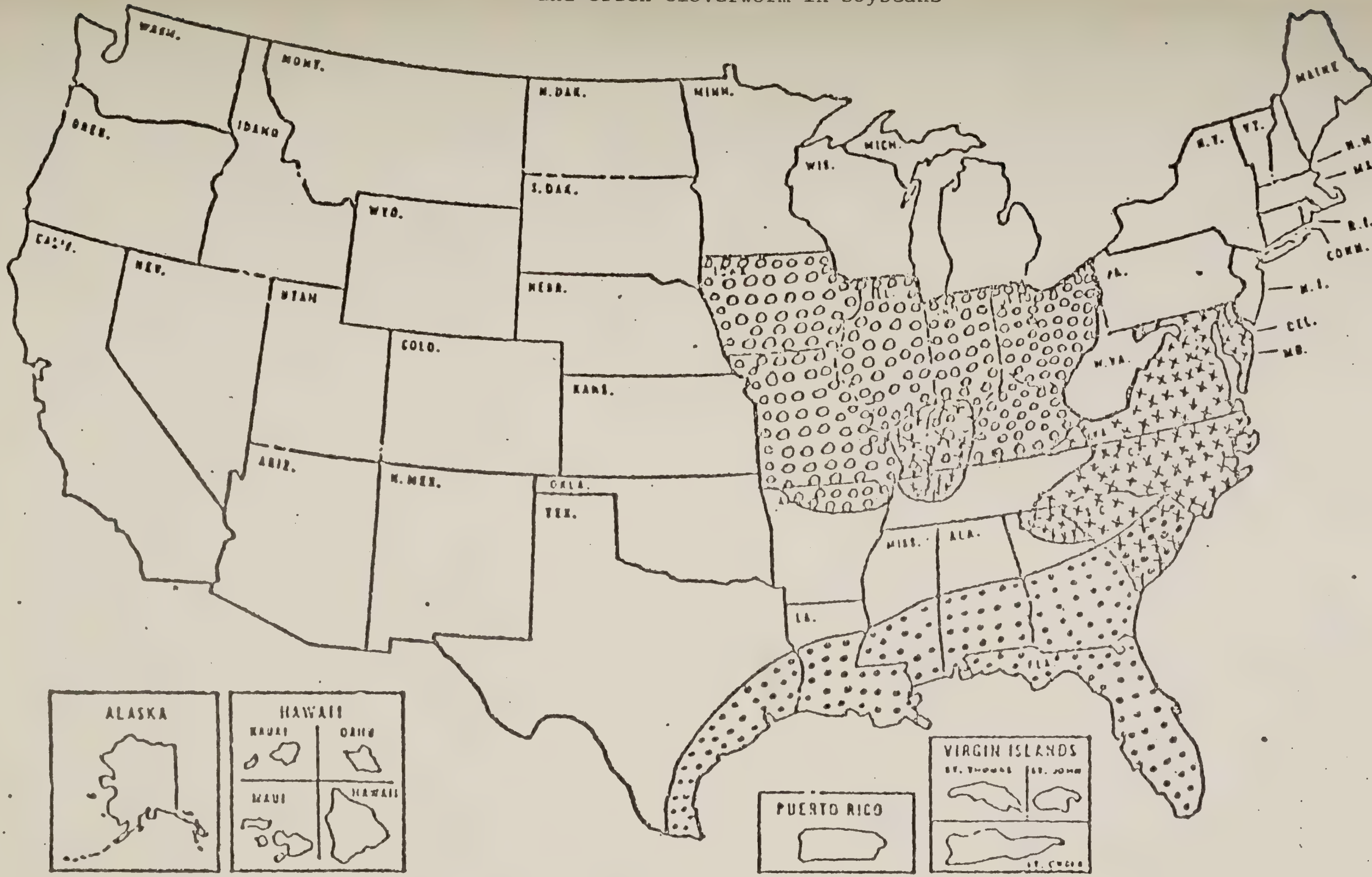
Insect problems on soybeans in the North Central region are sporadic, but they intensify from the mid-Atlantic states southward to the Southeast and Delta regions. In these regions annual insecticide treatments are often necessary and in some areas, for certain insects, several applications have to be made during the growing season.

BIOLOGICAL ASSESSMENT

Major Soybean Insects

Soybean insect pests of importance include bollworm (or corn earworm), soybean looper, stinkbugs, velvetbean caterpillar, Mexican bean beetle, and green cloverworm. Diflubenzuron does not control all of these pests, but is effective for the control of velvetbean caterpillar, Anticarsia gemmatalis, Mexican bean beetle, Epilachna varivestis, and green cloverworm, Plathypena scabra. These insects occur in relatively distinct regions of the country (Figure IV-1). The velvetbean caterpillar is a problem primarily in the Southeast and Delta regions, the Mexican

Areas of Major Infestation of Velvetbean Caterpillar, Mexican Bean Beetle and Green Cloverworm in Soybeans



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Source: Diflubenzuron Soybean Assessment Team, 1978

- Velvetbean caterpillar
- Mexican bean beetle
- Green cloverworm

bean beetle occurs mostly in the mid-Atlantic states and the green cloverworm is a problem primarily in the North Central region.

The acreage treated for each of these insects varies from year to year. However, the average acreage treated for each extent of infestation category is presented in Table IV-3. For example, in a year of limited infestation throughout the velvetbean caterpillar area, approximately 1.0 million acres would typically be treated, whereas in a year of extensive infestation, 6.2 million acres would be treated. The pattern of treatment for green cloverworm differs from the other two insects in that a "normal" infestation seldom occurs. Either an extremely limited acreage requires treatment or the pest is so widespread that extensive acreage is treated (Pedigo, 1978 and Blair, 1978).

The velvetbean caterpillar is by far the most serious of these 3 insect pests. As many as 8 insecticide applications of the currently used insecticides have been applied in a single season by growers in Florida for control of this pest (Greene, 1978). Prior to bloom, 50 percent defoliation of the soybean plant will not generally affect yields. The velvetbean caterpillar is such a voracious foliage feeder that its populations must be monitored carefully and at short time intervals (3-4 days) during the critical post-bloom pod-filling period. Timely control measures must be applied to avoid economic damage to the soybean crop. Left uncontrolled, foliage losses by this insect can easily reach 100 percent in September or October, drastically reducing yield (Herzog and Shepard, 1978).

Carner et. al. (1974) reported on the seasonal abundance of soybean insect pests in South Carolina. The velvetbean caterpillar is a late-season pest (August-October), preferring late planted and/or late maturing soybeans (Herzog, 1978). The Mexican bean beetle prefers snap-

Table IV-3

Area of Soybeans Treated for Velvetbean Caterpillar, Mexican Bean Beetle and Green Cloverworm[a/]

Insect and State	Extent of Infestation[b/]		
	Limited	Normal	Extensive
	-------------	1,000 acres	-----------
Velvetbean Caterpillar			
South Carolina	60	200	260
Georgia	100	750	1,000
Florida	0	0	287
Alabama - Mississippi	650	1,300	2,600
Louisianna	100	300	1,500
Texas	100	300	600
Arkansas - Oklahoma	10	0	0
Total	1,020	2,850	6,247
Mexican Bean Beetle			
Maryland - Virginia - Delaware	94	273	405
North Carolina	10	35	50
South Carolina	30	75	100
Georgia	20	70	100
Illinois - Indiana - Kentucky - Tennessee	15	0	0
Total	169	453	655
Green Cloverworm			
Illinois	10	0	500
Ohio	5	0	250
Iowa - Indiana - Missouri	40	0	800
Kentucky	5	0	0
Arkansas - Oklahoma	5	0	0
Total	65	0	1,550

a/ Developed by Diflubenzuron Soybean Assessment Team based on data from USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans", unpublished.

b/ The extent of infestation is the average annual number of acres requiring insecticide treatment for years in each infestation category, for each insect pest.

beans and lima beans to soybeans; therefore it tends to infest soybeans in mid season (June-August) when the preferred plant species are relatively less abundant (Dively, 1978). Green cloverworm, in general, infests soybeans earlier than do Mexican bean beetles or velvetbean caterpillars, but, except in the North Central region, do not pose an economic threat.

Currently Used Insecticides

Several insecticides are registered to control these 3 pests of soybeans. Table IV-4 lists some of these insecticides with standard formulations and application rates per acre.

The typical number of treatments of diflubenzuron and the currently used insecticides needed to control velvetbean caterpillar are displayed in Table IV-5. One treatment with diflubenzuron is sufficient to control velvetbean caterpillar regardless of the infestation level. With the currently used insecticides, several treatments may be needed to achieve control of this insect pest, depending on the level of infestation (low, moderate or high). In most of the states where this insect is a problem, one treatment of the currently used insecticides will usually control a low level of infestation, two treatments are needed to control a moderate level infestation and three treatments are needed to control a high level of infestation. In Florida, three treatments are usually needed for a moderate level infestation and five treatments for a high level infestation (Table IV-5).

Table IV-4

Registered Soybean Insecticides, by Insect

ɛect and ɛecticide	Formulation	Label Application Rates[a/] Formulation Rate	Rate A.I.
		units/acre	lbs./acre
.vetbean Caterpillar			
'arbaryl	80% Sprayable	2/3 - 1 1/4 lbs.	0.5 - 1.00
(ethyl parathion	4 lb. a.i./gal EC	1 pt.	0.5
'oxaphene + methyl parathion	6 + 3 lb. a.i./gal. EC	1/3 gal.	2 + 1
(ethomyl	90% Sol. Pwdr.	1/4 - 1/2 lb.	0.23 - 0.45
.cephate	75% Sol. Pwdr.	2/3 - 1 1/3 lb.	0.5 - 1.0
acillus Thuringiensis	7.26 bil. international units/lb.	1/4 - 1/2 lb.	0.25 - 0.5
ican Bean Beetle			
arbaryl	See VBC above		
ethomyl	See VBC above		
imethoate	4 lb. a.i./gal. EC	1 pt.	0.5
isulfoton	15% granular	6-7 lb.	1.0
oxaphene + methyl parathion	See VBC above		
en Cloverworm			
arbaryl	See VBC above		
oxaphene	6 lb. a.i./gal. EC	1 1/2 - 2 2/3 pt.	1.13 - 2.0
alathion	8 lb. a.i./gal. EC	30 oz.	1.9
ethomyl	See VBC above		
ethyl parathion	4 lb. a.i./gal. EC	1 qt.	1.0

U.S. EPA, "Compact Label File, 1976," unpublished.

Table IV-5

Number of Treatments Using Diflubenzuron and Currently Used Insecticides To Control Velvetbean Caterpillar on Soybeans[a/]

Insecticide	Treatments Per Year					
	Florida			Other States		
	Low	Moderate	High	Low	Moderate	High
Diflubenzuron	1	1	1	1	1	1
Currently Used						
Carbaryl	1	3	5	1	2	3
Methomyl	1	3	5	1	2	3
Methyl Parathion	1	3	5	1	2	3
Toxaphene + Methyl Parathion	1	3	5	1	2	3

a/ USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans," unpublished.

Insecticide treatments needed to control Mexican bean beetle and green cloverworm are not tabularized because both can generally be controlled with only one treatment of diflubenzuron or any of the currently used insecticides.

Depending upon geographic region, from 60-100 percent of the insecticides used for control of insect pests of soybeans are applied by air. Aerial spraying is preferred because: ground equipment cannot be used when fields are wet; the crop may be sown or grown in narrow rows; and application time by air is faster so the acreage to be treated can be covered in a shorter period of time. In addition, the possibility of economic damage, which may occur in the last fields treated when ground equipment is used, can be reduced or avoided with aerial application.

In 1977, two currently used insecticides and diflubenzuron were tested on soybean plots in South Carolina to determine their effect on predator insects and various lepidopterous larvae that attack soybeans (Table IV-6). All insecticides were applied on August 10.

The data indicate that diflubenzuron and carbaryl had little impact on the major natural predator complex (nabids and geocarids) either immediately after application or during the remainder of the growing season. Methyl parathion drastically reduced the number of predators present immediately after application but by the end of the growing season they had recovered and were approaching the number present in the check plot.

Diflubenzuron effectively controlled velvetbean caterpillar and green cloverworm as indicated by the larval counts late in the growing season. Methyl parathion and carbaryl gave immediate control (data not shown) but by the end of the growing season larval counts of velvetbean caterpillar and green cloverworm were about the same as in the check plot.

Table IV-6

Numbers of Predators and Lepidoptera Larvae in Three Meters of Row After Application of Insecticides to One-Fourth Acre Plots[a/]

Insecticide and Rate A.I./Acre	Predators (Nabids & Geocorids)						Velvetbean caterpillar		Green cloverworm			*Heliothis zea*			Loopers		
	8/15	8/22	8/30	9/7	9/12	9/19	10/3	10/10	9/7	9/12	9/19	8/15	8/22	8/30	9/7	9/12	9/19
Diflubenzuron 1.0 oz.	18	26	20	18	22	33	1	1	0	1	1	16	7	0	5	9	6
Methyl parathion 1.0 lb.	3	8	15	14	20	25	18	12	8	11	1	4	7	1	5	7	4
Carbaryl 0.75 lb.	14	19	25	20	27	37	28	14	9	9	3	2	8	0	3	9	6
Check	12	23	28	21	37	30	27	13	3	10	3	11	1	2	3	2	6

a/ Three one meter samples taken from each plot. Figures represent $\bar{x}$ of three repetitions. Insecticides applied 8/10/77. S.G. Turnipseed, Blackville, S.C., unpublished.

[illegible]

[illegible]

[illegible]

[illegible]

Diflubenzuron was ineffective in controlling Heliothis zea with larval counts being about the same as the check plot. Methyl parathion and carbaryl gave immediate control of Heliothis zea, but larval counts at later dates indicated a resurgence of the population.

The data comparing the effectiveness of the 3 insecticides on loopers is inconclusive. Carbaryl gave some initial control but larval counts 30 to 40 days after application were about the same for all materials.

Diflubenzuron

Diflubenzuron is mixed with water and applied as either a ground or aerial spray. A single application of diflubenzuron at 0.5 oz. a.i. per acre is sufficient to provide season-long control of the velvetbean caterpillar and the green cloverworm, and an application rate of 1 oz. a.i. per acre provides season-long control of the Mexican bean beetle (Turnipseed et. al., 1974; USDA/State/EPA, 1978). No resurgence or rapid increases in pest numbers were observed after diflubenzuron was applied, but currently used materials such as methomyl and methyl parathion allowed resurgences of target pest populations to levels above those in untreated check plots (Shepard, et. al., 1977). This was undoubtedly due to decimation of the natural predator complex by these highly toxic compounds.

Wilkinson (1976, 1977) reported that diflubenzuron at concentrations of $\geq$ 10 ppb did not produce significant mortality in several species of parasitoids and predators tested in the laboratory, although mortality of the Mexican bean beetle parasitoid, Pediobius foveolatus, was

significantly increased when parasitized beetle larvae were fed leaves dipped in 3 ppm of diflubenzuron (McWhorter and Shepard, 1977).

Some currently used insecticides and fungicides also have been shown to interfere with naturally-occurring entomogenous fungi, especially Nomuraea rileyi: (Ignoffo, et. al., 1975, Johnson, et. al., 1976), which is considered a key regulating agent for the velvetbean caterpillar, Heliothis zea, and green cloverworm larvae. Results of other laboratory tests revealed that diflubenzuron had no deliterious effects on the entomogenous fungus N. rileyi (Ignoffo, 1978) and preliminary tests at Clemson Univestsity suggest that certain concentrations of diflubenzuron may actually promote growth of the beneficial fungus (Sutton, 1978).

According to the "1978 Biological Survey for Diflubenzuron Use on Soybeans"1/, no increased yield effects are estimated for the substitution of diflubenzuron for currently used insecticides in areas infested with Mexican bean beetle or green cloverworm. However, the use of diflubenzuron to control moderate or high level infestations of velvetbean caterpillar is expected to increase soybean yields from 0.4 - 3.0 bushels per acre and 0.4 - 5.0 bushels per acre, respectively (Table IV-7).

1/ In the Spring of 1978, a questionnaire about diflubenzuron, infestations of velvetbean caterpillar, Mexican bean beetle and green cloverworm, and currently used insecticides to control these pests was sent by the Diflubenzuron Soybean Assessment Team to entomologists in states where these pests occur. The responses to this questionnaire combined with follow-up telephone conversations, in some cases, are referenced throughout this report as: USDA/State/EPA "1978 Biological Survey for Diflubenzuron Use on Soybeans," unpublished.

Table IV-7

Estimated Change in Soybean Yield Per Acre With Diflubenzuron Compared To Currently Used Insecticides, by Insect and Level of Infestation[a/]

Insect and State	Level of Infestation		
	Low	Moderate	High
	--------- bushels/acre ---------		
Velvetbean Caterpillar			
South Carolina	0.0	3.0	5.0
Georgia	0.0	1.5	3.1
Florida	0.0	0.4	1.2
Alabama & Mississippi	0.0	0.0	0.4
Louisiana	0.0	0.0	1.2
Texas	0.0	0.0	1.2
Arkansas & Oklahoma	0.0	--	--
Mexican Bean Beetle			
All States[b/]	0.0	0.0	0.0
Green Cloverworm			
All States[c/]	0.0	0.0	0.0

a/ Developed by the Diflubenzuron Soybean Assessment Team based on data from USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans," unpublished.
b/ States included: Maryland, Virginia, Delaware, North Carolina, South Carolina, Georgia, Illinois, Indiana, Kentucky and Tennessee.
c/ States included: Illinois, Ohio, Iowa, Indiana, Missouri, Kentucky, Arkansas and Oklahoma.

Non-Chemical Controls

There are ongoing efforts in several states to develop alternative non-chemical control strategies for the Mexican bean beetle and velvetbean caterpillar. Programs for the development of resistant soybean genotypes are currently being carried out at several geographic locations. Research in Maryland (Stevens et. al., 1975) and in South Carolina (Shepard and Robinson, 1976) has shown that the imported parasitoid, Pediobius foveolatus, can suppress populations of Mexican bean beetles in soybeans. The use of an insect virus from Brazil has shown promise for control of the velvetbean caterpillar (Carner and Turnipseed, 1977). However, commercial utilization of these alternative strategies on a practical basis is probably several years away.

Integrated Pest Management

Integrated pest management programs currently in use and under development emphasize the use of those pesticides which result in minimal environmental disturbance. The use of diflubenzuron could provide a valuable control tactic for integration into ongoing pest management systems and new programs as they are implemented. While the use of many currently available insecticides may result in resurgence of the target pest species and/or elevation of current secondary pests to a major status, the ability of diflubenzuron to provide season-long control of the target species will virtually eliminate the occurrence of target pest population resurgences. Additionally, the fact that diflubenzuron is minimally detrimental to the complex of beneficial organisms could

mean that the elevation of secondary nontarget pests to primary or economic pest status will also be averted. Thus, yield losses due to natural and induced pest outbreaks could be minimized.

Concurrent Insect Problems

There are other major insect pests of soybeans which are not controlled by diflubenzuron. These include the bollworm (*Heliothis zea*), loopers, (primarily *Pseudoplusia includens*), and a complex of stinkbugs. These may occur in concurrent infestations with the diflubenzuron-susceptible pests. When this occurs, a grower may elect to use a currently recommended insecticide which provides short-term control for the entire pest complex. In other situations, a grower may choose to use a currently recommended insecticide to give a rapid knockdown of the pest species and then apply diflubenzuron to provide season-long control of velvetbean caterpillar, Mexican bean beetle and green cloverworm.

When the pest complex occurs concurrently, reduction of the diflubenzuron-suspectible component may lower the total pest numbers to subeconomic levels. Under certain circumstances, dense populations of a pest such as the velvetbean caterpillar may necessitate the use of a currently available material along with diflubenzuron to provide immediate control and prevent reinfestation. By using diflubenzuron this way, the need for multiple applications of currently used insecticides could be eliminated.

ECONOMIC ASSESSMENT

In this economic assessment of diflubenzuron use on soybeans, both changes in insect control costs and soybean production resulting from substitution of diflubenzuron for currently used insecticides are evaluated at the grower level (user impacts). The impact on consumers is also addressed, but in somewhat less detail.

Procedures for Estimating User Impacts

The purpose of this section is to describe the origin of the estimated soybean acreage treated by insect and level of infestation, presented in Table IV-8, and to summarize key procedural steps and data sources.

1. Average number of acres treated annually with currently used insecticides to control velvetbean caterpillar, Mexican bean beetle and green cloverworm were estimated from the acreage (Table IV-3) and probability data (Appendix IV-C, Table 1) for three categories of extent of infestation - limited, normal and extensive. The sum of the products of each category's acreage and probability of occurrence represented an average year, accounting for the year-to-year variance in acreage treated.

2. The acreage within each infestation category was then distributed into two parts: the acreage treated for the target pest alone and the acreage treated for other insects occuring concurrently with the target insect. This distribution was estimated from data on the percent of acreage infested concurrently, along with the probability of a concurrent infestation (Appendix IV-C, Table 2).

3. The acreage within the limited, normal and extensive categories was distributed by level of infestation - low, moderate, or high - based on the probability of occurrence (Appendix IV-C, Table 3).

4. A set of application strategies specifying the circumstances under which diflubenzuron would be substituted for currently used insecticides were developed by the Diflubenzuron Soybean Assessment Team to allow estimation of the acreage treated with diflubenzuron.

5. The single-treatment cost per acre of diflubenzuron was estimated from the manufacturer's suggested retail price per pound active ingredient and the average application cost from custom applicators.

6. Single-treatment costs per acre of currently used insecticides were estimated from 1978 average retail prices per pound from distributor's price lists and the average application cost from custom applicators.

7. The value of production changes with diflubenzuron were estimated from weighted average yield increases, acreage affected and the three-year average (1975-1977) soybean price received by farmers of $5.78 per bushel (USDA, 1978a).

Key Assumptions and Limitations

1. It was assumed that the manufacturer-quoted retail price of $3.00 per ounce active ingredient for diflubenzuron would be the actual retail price if diflubenzuron were marketed for use on soybeans.

2. The results of this preliminary benefit analysis were based on a particular set of strategies for using diflubenzuron (specified in Table IV-11). Underlying this set of strategies was the assumption that diflubenzuron would be used on all soybean acreage currently treated with

insecticides to control the three insect pests specified in the analysis, except for the concurrently infested acreage with a low infestation level, where currently used insecticides would still be applied. This set of strategies maximized the acreage on which diflubenzuron might be expected to be applied.

3. The acreage infested in each extent of infestation category and their associated probabilities were subjectively determined by entomologists in the States affected based on their knowledge of insect problems in soybean production.

User Impacts

Acreage Treated - Currently Used Insecticides

The soybean acreage treated annually for the three insect pests susceptible for diflubenzuron was estimated at 3.0 million acres for velvetbean caterpillar, 365,000 acres for Mexican bean beetle and 325,000 acres for green cloverworm (Table IV-8). A majority of these acres were treated for the target pest alone. For velvetbean caterpillar, 2.0 million acres were treated for the pest alone, while 1.0 million acres were treated for this and other pests concurrently. Of the total 365,000 acres treated for Mexican bean beetle, all but 7,000 acres were treated for the pest alone. All of the acreage treated for green cloverworm was treated for the pest alone.

When the total of these acreages (pest-alone plus concurrent infestations) are examined from the perspective of level of infestation (low, moderate or high), most are in the "low" category (Table IV-8).

Table IV-8

Estimated Soybean Acreage Treated by Insect and Level of Infestation[a/]

Insect and Region	Insect Alone[b/]				Concurrent Insect Infestation[c/]				Total
	Low	Moderate	High	Total	Low	Moderate	High	Total	
	------- 1,000 acres -------								
Velvetbean Caterpillar									
Florida	32	119	65	216	11	39	21	71	287
Southeast[d/]	750	411	189	1,350	329	191	89	609	1,959
Delta/S. Plains[e/]	288	82	40	410	235	69	36	340	750
Total	1,070	612	294	1,976	575	299	146	1,020	2,996
Mexican Bean Beetle[f/]	358	--	--	358	7	--	--	7	365
Green Cloverworm[g/]	325	--	--	325	0	--	--	0	325

a/ Developed by the Diflubenzuron Soybean Assessment Team based on data from, USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans", unpublished.
b/ Acreage on which target insect is the only insect requiring treatment.
c/ Acreage on which other insects require treatment concurrently with the target insect.
d/ South Carolina, Georgia, Alabama, Mississippi.
e/ Louisiana, Texas, Arkansas, Oklahoma.
f/ States included: Maryland, Virginia, Delaware, North Carolina, South Carolina, Georgia, Illinois, Indiana, Kentucky, Tennessee.
g/ States included: Illinois, Ohio, Iowa, Indiana, Missouri, Kentucky, Arkansas, Oklahoma.

[illegible]

For velvetbean caterpillar, the total 3.0 million acre are distributed as follows: 1.6 million acres (55 percent) in the low infestation category, 0.9 million acres (30 percent) in the moderate infestation category and 0.4 million acres (15 percent) in the high infestation category. For Mexican bean beetle and green cloverworm, all the acreage treated is in the low infestation category.

Currently, at least two insecticides are widely used to control each of these three insect pests. For the control of velvetbean caterpillar in the Southeast, carbaryl is used on the majority (70 percent) of the acreage treated (Table IV-9). The remaining 30 percent of the soybean acreage treated in this region is divided among methomyl, methyl parathion, and toxaphene + methyl parathion. In the Delta and Southern Plains, methyl parathion is used on 75 percent of the acreage treated for velvetbean caterpillar and the remaining 25 percent is treated with carbaryl and methomyl.

The major insecticides used to control Mexican bean beetle are carbaryl and methomyl, accounting for 60 percent and 40 percent of the acreage treated, respectively (Table IV-10). To control green cloverworm, growers are currently using carbaryl (65 percent of the treated acreage), malathion (25 percent) and toxaphene (10 percent). Other insecticides are also used to control these three pests, but their use is insignificant and not considered in this study.

Table IV-9

Distribution of Treated Acreage Among Major Currently Used Insecticides to Control Velvetbean Caterpillar on Soybeans

Insecticides	Distribution of Treated Acreage[a/]	
	Southeast[b/]	Delta and Southern Plains[c/]
	------------- percent -------------	
Carbaryl	70	20
Methomyl	15	5
Methyl Parathion	5	75
Toxaphene + Methyl Parathion	10	--[d/]

a/ Developed by the Diflubenzuron Soybean Assessment Team, based on information from team members and USDA, ESCS, "1976 National Pesticide Usage Survey," unpublished.
b/ South Carolina, Georgia, Florida, Alabama, Mississippi.
c/ Louisiana, Texas, Arkansas, Oklahoma.
d/ No use reported.

Table IV-10

Distribution of Treated Acreage Among Major Currently Used Insecticides to Control Mexican Bean Beetle and Green Cloverworm on Soybeans

Insect and Insecticide	Distribution of Treated Acreage[a/]
Mexican Bean Beetle	
Carbaryl	60
Methomyl	40
Green Cloverworm	
Carbaryl	65
Malathion	25
Toxaphene	10

a/ Developed by the Diflubenzuron Soybean Assessment Team based on information from USDA, ESCS, "1976 National Pesticide Usage Survey," unpublished, and personal communication with Dr. L. P. Pedigo, Iowa State University, August 3, 1978.

Acreage Treated- Diflubenzuron

Diflubenzuron is not currently registered for use on soybeans. Therefore, to estimate the per acre treatment cost and annual costs if diflubenzuron should become available to growers, a set of application strategies and assumptions was developed (Table IV-11). Several alternative strategies obviously exist, but the set used in this analysis was selected to estimate the maximum acreage on which diflubenzuron could reasonably be expected to be used.

It was assumed that on the soybean acreage where velvetbean caterpillar occurred alone, one application of diflubenzuron would replace the current insecticide treatment schedule (see Table IV-5) regardless of the infestation level. Currently used insecticides would provide equal control at this infestation level, but a farmer does not know if the initial infestation level early in the season will lead to a higher level infestation later in the season. Therefore, it has been assumed that he will choose to eliminate the risk of having to treat again later by using diflubenzuron the first time.

On the acreage where veletbean caterpillar was present concurrently with other insect pests, it was assumed that currently available insecticides would be applied at low infestation levels. For moderate or high infestation levels on acreage with a concurrent pest problem, it was assumed that growers would first use a currently available insecticide to obtain control of the entire insect complex and then apply diflubenzuron which would provide season-long control of velvetbean caterpillar.

Table IV-11

Application Strategies to Control Various Levels of Infestation of Velvetbean Caterpillar, Mexican Bean Beetle, and Green Cloverworm on Soybeans if Diflubenzuron is Available for Use[a/]

Insect	Insect Alone[b/]			Concurrent Insect Infestation[c/]		
	Low	Moderate	High	Low	Moderate	High
Velvetbean Caterpillar	D[d/]	D	D	C[e/]	C&D[f/]	C&D
Mexican Bean Beetle	D	--	--	C	--	--
Green Cloverworm	D	--	--	C	--	--

a/ Developed by the Diflubenzuron Soybean Assessment Team.
b/ The acreage to receive treatment is infested with only the target pest (at levels requiring control).
c/ The acreage to receive treatment is infested with other insects in addition to the target pest (at levels requiring control).
d/ "D" represents one treatment with diflubenzuron.
e/ "C" represents one treatment with a currently used insecticide.
f/ "C and D" represents two treatments, one with a currently used insecticide and one with diflubenzuron.

For Mexican bean beetle and green cloverworm, it was assumed that one application of diflubenzuron would replace the currently used insecticides on the acreage where these pests occurred alone. Where Mexican bean beetle and green cloverworm were present concurrently with other insects, it was assumed that currently available insecticides would be used because they would control the entire pest complex. No treatment is specified for moderate and high infestation levels because Mexican bean beetle and green cloverworm can generally be controlled with one application of diflubenzuron or the currently used materials regardless of infestation level.

Treatment Costs Per Acre

The single-treatment cost for diflubenzuron was estimated at $4.25 per acre for velvetbean caterpillar and green cloverworm control, and $5.75 per acre for Mexican bean beètle control. Comparable single-treatment costs for currently used insecticides ranged from $3.87 to $7.97 per acre (Table IV-12).

At low infestation levels the annual treatment costs for some currently used insecticides are lower than diflubenzuron (Table IV-12). As the level of infestation for velvetbean caterpillar intensified, the differential between annual treatment cost per acre with diflubenzuron and the currently used insecticides increased. This situation was most noticeable for control of velvetbean caterpillar in Florida where five treatments with currently used insecticides are normally used at high infestation levels and would be replaced by one application of diflubenzuron.

Table IV-12

Application Rate, Retail Price and Treatment Costs per Acre of Diflubenzuron and Currently Used Insecticides, by Insect and Level of Infestation

ect ecticide	Application Rate[a]	Retail Price[b]	Single-Treatment Cost Per Acre: Insecticide Material	Application[c]	Total	Annual Treatment Cost Per Acre[d] — Florida: Low	Moderate	High	Other: Low	Moderate	High
	lbs a.i./acre	$/lb a.i.	dollars/acre								
etbean Caterpillar											
Diflubenzuron	.03125	48.00	1.50	2.75	4.25	4.25	4.25	4.25	4.25	4.25	-.25
Currently Used											
Carbaryl	.50	2.48	1.24	2.75	3.99	3.99	11.97	19.95	3.99	7.98	11.97
Methomyl	.25	11.60	2.90	2.75	5.65	5.65	16.95	28.25	5.65	11.30	16.95
Methyl Parathion	.50	2.25	1.12	2.75	3.87	3.87	11.61	19.35	3.87	7.74	11.61
Toxaphene + Methyl Parathion	1.50 + .50	--[e]	3.05	2.75	5.80	5.80	17.40	29.00	5.80	11.60	17.40
can Bean Beetle											
Diflubenzuron	.0625	48.00	3.00	2.75	5.75	--	--	--	5.75	--	--
Currently Used											
Carbaryl	.50	2.48	1.24	2.75	3.99	--	--	--	3.99	--	--
Methomyl	.45	11.60	5.22	2.75	7.97	--	--	--	7.97	--	--
n Cloverworm											
Diflubenzuron	.03125	48.00	1.50	2.75	4.25	--	--	--	4.25	--	--
Currently Used											
Carbaryl	.75	2.48	1.86	2.75	4.61	--	--	--	4.61	--	--
Malathion	1.00	2.56	2.56	2.75	5.31	--	--	--	5.31	--	--
Toxaphene	2.00	.96	1.96	2.75	4.67	--	--	--	4.67	--	--

USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans," unpublished.
Diflubenzuron price based on manufacturer suggested retail price of $3.00 per ounce active ingredient. All other prices are 1978 averages from various distributors' price lists.
Developed by the Diflubenzuron Soybean Assessment Team based on information from custom applicators.
Single-treatment cost per acre times number of treatments per year (Table III-5 for velvetbean caterpillar; 1 treatment per year for Mexican bean beetle and green cloveworm).
Since the insecticide contains two active ingredients, it is inapplicable to calculate a price per pound active ingredient.

To estimate savings in insect control cost from using diflubenzuron, weighted average annual treatment costs per acre of the currently used insecticides were calculated for each insect pest (Table IV-13). The weighted average annual treatment costs per acre for velvetbean caterpillar ranged from $3.98 for a low infestation in the Delta and Southern Plains to $22.05 for a high infestation in Florida. Annual treatment costs were estimated at $5.58 per acre for Mexican bean beetle and $4.79 per acre for green cloverworm.

The annual savings in control costs per acre from using diflubenzuron were estimated separately for acreage infested with velvetbean caterpillar alone and concurrently with other insect pests. At the low infestation level with velvetbean caterpillar alone, the annual cost saving was $0.16 per acre when diflubenzuron replaced the current insecticides in Florida and the other Southeastern States (Table IV-13). In the Delta and Southern Plains, growers would experience increased costs of $0.27 per acre when using diflubenzuron compared to the current insecticides. As the infestation level intensified, the cost savings increased because one application of diflubenzuron substituted for multiple applications of the current insecticide (Table IV-5). Cost savings were greater for Florida because more applications of the current insecticides were needed to achieve control than in the other regions.

No estimate was made for a low infestation of velvetbean caterpillar with concurrent insect infestations because it was assumed that the currently available insecticide would be used to control the entire pest complex. As the infestation level intensified, the cost savings increased for the same reason explained above. However, these savings

Table IV-13

Average Treatment Cost Savings Per Acre From Using Diflubenzuron, By Insect[a/]

Insect and Region	Weighted Average Annual Treatment Cost Per Acre[b/] for Current Insecticides			Diflubenzuron Treatment Costs Per Acre[c/]	Treatment Cost Savings Per Acre Using Diflubenzuron[d/]					
					Insect Alone			Concurrent Insect Infestation		
	Low	Moderate	High		Low	Moderate	High	Low	Moderate	High
	dollars/acre									
Velvetbean Caterpillar										
Florida	4.41	13.23	22.05	4.25	0.16	8.98	17.80	--	4.57	13.39
Southeast	4.41	8.82	13.23	4.25	0.16	4.57	8.98	--	0.16	4.57
Delta & Southern Plains	3.98	7.96	11.94	4.25	-0.27	7.69	7.69	--	-0.27	3.71
Mexican Bean Beetle	5.58	--	--	5.75	-0.17	--	--	--	--	--
Green Cloverworm	4.79	--	--	4.25	0.54	--	--	--	--	--

a/ Developed by the Diflubenzuron Soybean Assessment Team.
b/ Annual treatment costs from Table IV-12 weighted by the distribution of treated acreage in Tables IV-9 and IV-10.
c/ Diflubenzuron treatment costs reported in Table IV-12.
d/ See Table IV-11 for treatment strategies underlying these cost differences.

were lower than for the comparable insect-alone category in the concurrent infestation category, because an application of a currently used insecticide was assumed to be used in addition to the single diflubenzuron application.

Estimated treatment cost savings per acre from using diflubenzuron to control Mexican bean beetle and green cloverworm, were considerably smaller overall than for velvetbean caterpillar. For acreage infested with Mexican bean beetle, an increased cost of $0.17 per acre was estimated while a savings of $0.54 per acre was estimated for acreage infested with green cloverworm. Both of these estimates pertain to acreage infested with the target insect pest alone. No savings for concurrently infested acreage were estimated since, under the strategy adopted for this analysis (Table IV-11), no diflubenzuron would be used.

Aggregate Treatment Costs

Aggregate treatment cost savings from using diflubenzuron to control velvetbean caterpillar, Mexican bean beetle and green cloverworm were estimated to be $7.6 million annually (Table IV-14). Of this total, $7.5 million were for velvetbean caterpillar control, and $176,000 for green cloverworm control. Control cost for Mexican bean beetle was estimated to increase by $61,000. The majority of the savings from controlling velvetbean caterpillar, $4.1 million, occurred in the Southeast (excluding Florida). Additional savings of $2.7 million were estimated for Florida.

Table IV-14

Aggregate Annual Treatment Cost Savings from Using Diflubenzuron to Control Selected Pests of Soybeans, by Insect[a/]

Insect and Region	Insect Alone				Concurrent Insect Infestation				Total
	Low	Moderate	High	Total	Low	Moderate	High	Total	
	----------------	----------------	----------------	1,000 dollars	----------------	----------------	----------------	----------------	----------------
Velvetbean Caterpillar									
Florida	5	1,069	1,157	2,231	--	178	281	459	2,690
Southeast	120	1,878	1,697	3,695	--	31	407	438	4,133
Delta and Southern Plains	- 78	304	308	534	--	- 18	134	116	650
Total	47	3,251	3,162	6,460	--	191	822	1,013	7,473
Mexican Bean Beetle	- 61	--	--	- 61	--	--	--	--	- 61
Green Cloverworm	176	--	--	174	--	--	--	--	176
						Total			7,588

a/ Developed by the Diflubenzuron Soybean Assessment Team.

Since diflubenzuron is highly selective among insects, the majority of the savings in treatment costs accrued to acreage infested with the target insect alone. For velvetbean caterpillar, $6.5 million (86 percent) of the $7.5 million savings, was on acreage infested with this insect alone (Table IV-14). For acreage infested with Mexican bean beetle and green cloverworm, all of the savings fell into this category.

Evaluated by level of infestation, $7.4 million (98 percent), of the $7.6 million total savings were from the control of moderate and high level infestations of velvetbean caterpillar. The remaining $162,000 savings (2 percent) were from low level infestations of all three insect pests.

Change in Value of Production

The use of a different insecticide can sometimes result in production changes in addition to changes in insect control costs. In this analysis of diflubenzuron, yield changes were estimated to occur on soybean acreage infested with velvetbean caterpillar at moderate and high infestation levels, but not at low infestation levels. No yield changes were estimated to occur on acreage infested with Mexican bean beetle or green cloverworm.

The use of diflubenzuron was estimated to increase soybean yields on velvetbean caterpillar infested acreage by an average of 0.41 bushels per acre on moderately infested acreage and 1.44 bushels per acre on highly infested acreage (Table IV-15). A total increase in production of 1.0 million bushels annually was estimated, 374,000 bushels on moderately infested acreage and 633,000 on highly infested acreage.

Based on a three-year average price of $5.78 per bushel, the increased value of soybean production was estimated to be $5.8 million annually. The majority, $3.7 million, was from acreage with a high level of velvetbean caterpillar infestation.

Regionally, the Southeast accounted for most of the increased value of production at $3.7 million. Florida, which accounts for only 10 percent of the total acreage infested with velvetbean caterpillar, was estimated to account for 18 percent of the increased value of production-$1.1 million. Acreage in the Delta and Southern Plains Region accounted for the remaining $1.0 million.

Summary

In summary, almost all of the insect control cost savings and all of the increase in soybean production from substituting diflubenzuron for currently used insecticides were estimated to occur on acreage infested with velvetbean caterpillar at moderate and high levels of infestation. Infestation at these levels occur annually through time, averaging 45 percent of the acreage infested with velvetbean caterpillar and 98 percent of the savings. A slight increase in control cost were estimated for Mexican bean beetle control and only marginal savings were estimated for green cloverworm control.

The cost per acre-treatment with diflubenzuron lies within the range of costs of the currently used insecticides. The major advantage of using diflubenzuron is its ability to provide season-long control of velvetbean caterpillar with only a single treatment, regardless of the level of infestation, whereas currently used insecticides require additional treatments at higher infestation levels.

Table IV-15

Annual Value of Increased Production
from Using Diflubenzuron to Control
Velvetbean Caterpillar by Level of Infestation and Region

Region and Level of Infestation	Increased Yield[a/]	Estimated Area Affected[b/]	Increased Production	Annual Value of Production Increase[c/]
	bu./acre	1,000 acres	1,000 bu.	$1,000
Florida				
Moderate	0.41	158	65	376
High	1.44	86	124	716
Total	--	--	189	1,092
Southeast				
Moderate	0.41	602	247	1,428
High	1.44	278	400	2,312
Total	--	--	647	3,740
Delta and Southern Plains				
Moderate	0.41	151	62	358
High	1.44	76	109	630
Total	--	--	171	988
Total	--	--	1,007	5,820

a/ Appendix IV-B.
b/ Table IV-8
c/ A price received of $5.78/bushel was used in these calculations. This is a weighted average of the season average soybean prices received by farmers for the years 1975 to 1977.

Consumer Impacts

No consumer impacts were estimated. The estimated increase in production of 1.0 million bushels resulting from the use of diflubenzuron is only 0.07 percent of the 1.5 billion bushel average annual U.S. soybean production (Table IV-1). This effect on production is too small to have any effect on soybean prices.

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V. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZUON USE FOR TUSSOCK MOTH

PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT
FOR DOUGLAS FIR TUSSOCK MOTH

CURRENT USE ANALYSIS

Current Registrations

Naled and methoxychlor are registered for ground application only. Carbaryl, currently undergoing RPAR review, is the only chemical registered for aerial control of the Douglas fir tussock moth. Non-chemical controls include Bacillus thuringiensis (B.t.) and Nuclear polyhedrosis virus (NPV).

Use of DFB

DFB is currently not registered for tussock moth control. However, the Forest Service has an experimental permit for use in field research.

PERFORMANCE EVALUATION OF DFB AND ALTERNATIVES

Pest Infestation and Damage

Biological Summary

The first report of Douglas-fir tussock moth a native pest in the United States, was on the Sierra National Forest, California, 1906.

Forest's frequently have intermingling property ownership over large areas which, when Douglas-fir tussock moth outbreaks occur, cause survey, control and financial problems that extend beyond the capabilities of single land owners. The Douglas-fir tussock moth prefers to feed on Douglas-fir white fir, and grand fir.

All feeding is done during the larval stage. The young larvae eat the underside of new needles. Later, older needles are eaten or severed near their base. Severely, infested trees can be completely

stripped in one season and will die.

Immediately after a tussock moth outbreak, tree growth patterns change. Defoliation causes significant decreases in ring width at all levels of tree height, but the magnitude of the decrease is proportionally greater in the upper part of the tree where feeding damage is usually heaviest. The average reduction during the 3 years of greatest growth depression calculated as a percentage of the growth during the 4 years immediately preceeding reported in one study was as follows: heavy defoliation, 74 percent; moderate defoliation, 67 percent; light defoliation, 31 percent (Wickman, 1963). Growth recovery was not complete until the 4th and sometimes the 5th year following the attack.

Tree mortality, top-kill and growth loss resulting from defoliation by the Douglas-fir tussock moth in 1972 and 1973 in the Blue Mountains of Oregon and Washington were measured annually from 1973 through 1976 on a series of permanent field plots. The study was designed to use the defoliation intensity in 1972 and 1973 as a predictor of tree mortality and top-kill during and after the outbreak. Results of this study show that tree mortality and growth loss are directly related to the degree of defoliation.

The primary damages from Douglas-fir tussock moth outbreaks are loss of trees suitable for lumber and wood products and tree growth. Defoliation damage tends to increase the amount of water run off but the impact on water quality seems to be insignificant. Impacts on recreation are minimal with the positive (increased hunting)

about balancing out the negative (esthetic and recreation utility) effects. Impacts on terrestrial wildlife tend to be small and positive and those on fish negligible. The potential for severe resource damage due to wildfires in defoliated stands, however, is significantly increased.

Comparative Performance

The overall objective of Douglas-fir tussock moth control is to reduce the damage and loss caused by this insect on all forest lands commensurate with forest resource and other environmental values involved. The control strategy is to prevent as much defoliation and tree loss as possible thus avoiding most of the timber losses and need for extra fire protection expenses.

Comparative Efficacy

An analysis of available information indicates that diflubenzuron is the most promising of all materials tested as a substitute for DDT. Field tests during 1975 and 1976 in British Columbia, Canada, proved DFB to be highly effective chemical control for tussock moth agent. The material was very effective when applied at 4 ounces a.i. per acre, 99.7, 92.2, and 86.6 percent, respectively, of the tussock moth larvae in the sprayed area were killed during 1976. The registration application for DFB on Douglas-fir tussock moth will specify a 2 to 4 ounce a.i. per acre rate. Some of the efficacy data indicated that this dosage rate could possibly be lower.

Carbaryl is considered less desirable than DFB because of possible biological side effects at the necessary dosage of 2 pounds a.i. per

acre. Bacillus thuringiensis does not appear to be consistently effective at the registered level. Nuclear polyhedrosis virus is not commercially available ; DDT, the traditional control, is an effective and less expensive than DFB but has been cancelled due to adverse effects on non target organisms.

The factors to be considered in the selection of a control agent for Douglas-fir tussock moth control are summarized on Tables V-1, V-2, and V-3. Acephate is included because of its control potential based on tests conducted in 1975 and 1976. Only aerial spraying is considered because ground control is not feasible on most of the sites.

ECONOMIC IMPACT ANALYSIS

Profile of the Impact Area

Many communities in the inland Pacific Northwest are heavily dependent on the timber industry. Because the U.S. Forest Service is responsible for managing a major portion of timber supplies it develops timber growing and harvest plans to provide for a continuous and stable supply of material for local mills. Other major land owners (states, timber companies) typically operate with similar plans. Any disruption of this steady flow of timber, brought about by heavy losses from insect attacks, will have immediate impacts on local processing plants and the local economies. Accelerated harvest of salvage timber may exceed local mill capacities and require increased log transport cost to more distant mills. More seriously, a severe reduction of the timber base from epidemic losses may require a reduction of the planned annual sales, thus curtailing mill supplies and economic activity for many years. Additional local government impacts are felt when Forest Service sales revenues are altered since counties receive 25 percent of these revenues in lieu of property taxes.

User Impacts

The immediate impact of an epidemic outbreak of the Douglas-fir tussock moth affects timber management and the flow of timber from the forest. Approximately 2/3 of the susceptable forest stands are publicly owned (state and federal government); the remainder are largely industrially owned forests. Most of these forests are managed for long-term production of commercial timber producing a continuous flow of harvested trees for

for processing at local mills. A major uncontrolled tussock moth epidemic would result in large quantities of dead and severly injured timber.

After an infestation harvesting costs would increase due to the irregular distribution of dead and damaged trees. Wood value would be lost progressively with time as decay developed following the death of a tree. Many trees would need to be cut before reaching mature size, sacrificing potential high value growth. The heavy accumulations of dead trees and logging debris would create a potential for forest fires, which could result in heavy timber losses and high protection and control costs. Many infested areas may require clear cutting followed by prompt replanting to replace lost growing stock. The orderly plans for forest management may be disrupted with resultant reduction of future harvests for many years.

As a practical matter the value of the timber salvaged may be only a fraction of original value;fire presuppression and suppression cost may increa: many-fold for several years; injured trees may fall prey to secondary insects; forest planting rates may need to be increased to many times beyond the normal replanting rate.

Because future attacks cannot be predicted, the necessity to deal with the problem cannot be planned and scheduled. Current efforts are directed at surveilance and early detection to provide some lead time for organizing control efforts. The only alternative operational control to DFB for a major outbreak is aerial spray with carbaryl with accompanying undesirable side effects. Research continues to seek more effective controls.

Analytic Approach

The following quantification of potential impacts is based on a hypothetical infestation on 500,000 acres of which 350,000 acres would be treated. Damage and mortality estimates from the last major tussock moth attack of 1972-74 form a basis for this analysis. Costs associated with timber management were developed by the study team (Table V-4). Three control options were evaluated: carbaryl, diflubenzuron and no control. The efficacy of DFB and carbaryl to control tussock moth was assumed to be the same. The expected level of insect population control with either chemical is assumed to be 90 percent. Forest managers would prefer to use diflubenzuron if available, because carbaryl has unwanted side effects even though the economic benefits of its use are estimated to be greater than for diflubenzuron.

Summary of net losses

The assumed uncontrolled Douglas-fir tussock moth outbreak on the 350,000 acres treated is estimated to result in losses of $38.37 million; $18.10 million reduction in timber value, $5.82 million for increased planting cost, $14.45 million additional fire costs. Losses on the remaining 150,000 acres infested but not sprayed were considered to be negligable. (Table V-5).

Use of either DFB or carbaryl is expected to reduce timber losses of the hypothetical outbreak by $16.3 million and reduce additional planting costs by $5.24 million. The additional fire control costs would be reduced by $7.25 million if DFB were used, $11.55 million if carbaryl were used. Control costs of $3.73 million are expected for DFB, $2.77 million for carbaryl, (Table V-6).

Timber losses

A number of assumptions were made concerning the biological and management conditions under which Douglas fir and true fir are grown. (Table V-4). In some cases these assumptions were expressed as a low and high estimate to cover the wide variability of conditions expected to exist in the forest. Typical values are approximated by the midpoints of values calculated from these ranges. Mortality and growth losses for both mature and immature stands are calculated from the acreages expected to be found in various defoliation severity classes. Expected salvage recovery was substracted from these losses. The methodology for this analysis is presented in The Economic Appendix. A breakdown of the 350,000 acr sprayed into defoliation classes, the midpoint of estimated timber loss per acre, and the reduction in loss due to DFB control are presented in Table V-7.

Fire Costs

Tussock moth control also results in reduced fire presuppression and suppression costs. This beneift is highly dependent upon weather conditions. It is also highly dependent upon the accessability of the defoliated areas to fire suppression crews. These conditions vary widely over the possible infestation area. In many cases the injured stands of timber will necessitate an increase in presuppression costs, fuel management costs, and suppression costs. The risk of fire is increased by the presence of salvage operations. Areas of standing dead timber increase both the likelihood of rapid fire spread and of crown fires. Premature dying of foliage, twigs, and branches of surviving trees contributes to the dead

fuel loading. In areas of high fuel hazard with heavy loadings of smaller size dead fuels, combustion is more rapid, heat more intense and organic matter consumption more complete.

From the 1972-1974 estimates of the increased fire management costs due to the tussock moth outbreak, the expected costs ranged from $15.1 to $21.3 million. If these costs are assumed to be representative of the costs to be experienced over the region in general the expected increased fire management costs for the 350,000 acre control area would range from $11.99 to $16.9 million.

From the biological data, it is expected that DFB is not as effective in reducing the fire hazard as was DDT. This reduced effectiveness is caused by the delayed killing action of DFB. It is hoped that on an control area the spraying of DFB would reduce the fire management costs by at least one_half or by $6 to $8.5 million. Should carbaryl be used for control, its effectiveness would be expected to reduce these costs by 80 percent.

Planting Costs

It was assumed by the study team that one-half of the Dead and Class I acreages would need to be planted. The remainder of the Dead and Class I lands would regenerate naturally. This estimate was considered to be conservative. Reforestation costs were estimated to range from $120 to $300/acre. This range would cover the wide variety of conditions expected to be encountered. The total acreage in Dead and Class I land is 55,500 acres. The acreage replanted is 27,750 acres. Costs are expected to range from $3.33 to $8.32 million.

Microeconomic and Social/Community Impacts

The impact on local or regional economies from a major uncontrolled tussock moth attach can be severe. Accelerated harvests will require additonal logging activity, added processing plant activity and/or increased log hauling to more distant mills. During the salvage period, typically 1-2 years, employment and economic activity will be increased. Lumber and plywood mills may produce greater than normal outputs. However, a quality loss may be associated with the salvaged timber. Additionally, manpower will also be necessary for fire suppression and presuppression operations. Long range impacts are dependant upon the degree to which the sustained annual yield of the local timber supply is disrupted.

Limitations of Analysis

A principal source for biological and operational data was the USFS final Environmental Impact Statement prepared for the tussock moth control plan in 1974. No data for ex-ante losses and induced costs were available from the 1971-74 outbreak. All costs were ex-post. No operational experience has been accumulated for the use or effectiveness of either carbaryl or DFB; these estimates are based on limited testing on tussock moth.

Table V-1

Comparison of environmental factors of control agents tested for control of Douglas fir tussock moth

	DDT	Carbaryl	Diflubenzuron	Acephate	B.t. a/	NPV b/
Target Specific (non-broad spectrum)	No	No	Fair	No	Fair	Yes
Adverse Direct Effects on Non-target Organisms:						
Beneficial parasites and predators	Yes	Yes	No c/	Yes	No	No
Pollinating insects	Yes	Yes	No	Yes	No	No
Aquatic invertebrates	Yes	Yes	Yes	Yes	No	No
Fish	Some	Some	No	No	No	No
Birds	Some	Some	No	Some	Some	No
Crustaceans	Yes	Yes	Yes	No	No	No
Mollusks	Yes	Yes	No	Yes d/	No e/	No
Half Life-Water	1½ yrs	3-4 days	1-10 days	3-15	Short e/	Unknown
Persistence-Soil	3-4 yrs	8-10 days	24 hours f/	½ - 4 days	Short	Up to 10 yrs
Biomagnification	Yes	No	No	No	No	No
Territory abandonment by birds	Yes	Yes	No	Yes	No	No

a/ Bacillus thuringinsis
b/ Nuclear polyhedrosis virus
c/ Primarily yellowjackets.
d/ In field tests under actual use conditions. Considerable longer times reported in laboratory tests.
f/ In field tests sprayed on soil surface; 1/2 to 1 week in laboratory tests where Dimilin was incorporated into the soil. Depends on amount of microbial action.
e/ For both water and soil. Spores hatch quickly in the presence of moisture and thus are not separable from other bacteria.

Table V-2

General considerations

	DDT	Carbaryl	Diflubenzuron	Acephate	B.t.	NPV
Registration Status	Cancelled Sec. 18 possible	Yes	No	No	Yes	Yes
Tolerance on Agr. Crops	Yes	Yes	No	Yes	N/A	N/A
Monitoring Requirements	High	High	Low a/	High	Low	Low
Commercially available	Yes	Yes	Yes	Yes	Yes	No
Efficacy b/	98%	95%	98%	87%	85% c/	98% d/
Time Span of Control	Excellent	Good	Excellent	Fair	Poor	Poor e/
Operational feasibility	Proven	Not proven	Not proven	Not proven	Not proven	Not proven
Rain Resistant	Yes	Yes	Yes	No	No	No
Foilage protection	90%	70-80%	50%	70-80%	80%	30%
Tree Mortality Prevention f/	Excellent	Good	Good	Good	Good	Unknown
Growth Loss Prevention f/	Excellent	Good	Good	Good	Good	Poor
Fire Hazard Prevention f/	Excellent	Good	Poor	Fair	Good	Poor

a/ Except for yellowjackets and crustaceans.
b/ In terms of insect mortality using registered or most effective dosage rates (Region 6, 1974. and Graham, 1975)
c/ At the 2 pound rate per acre with sunscreen material and molasses added.
d/ At the end of annual insect life cycle. Only proven on high density populations. Not sure of efficacy on incipient outbreak.
e/ The actual life of the virus on the foliage is short, but due to infectious nature between insects, the span of control is excellent (if insect populations are high enough).
f/ Assuming material is applied in first year of outbreak cycle.

Table V-3

Application rate and cost per acre based on a single application per year

Per acre	DDT	Carbaryl	Diflubenzuron	Acephate	B.t.	NPV
Dosage per application	0.75 lb. a.i.	2.0 lbs. a.i.	2 to 4 oz. a.i.	1.0 lb. a.i.	1.0 to 2.0 qts d/	14.3 grams
Total material including carrier applied per acre	1 gal.	1 gal.	1 gal.	1 gal.	1 gal.	1 gal.
Carrier	Fuel oil	Fuel oil	Water	Water	Water	Water
Material cost per application	$ .35	$4.92	$5.10 to 10.20 b/	$4.50	$4.00 to $8.00	Not available c/
Applicator cost per application	$2.90	$3.00 d/	$3.00	$3.00	$4.50 e/	$4.50 e/
Total cost per year	$3.35	$7.92	$8.10 to $13.20	$7.60	$8.50 to $12.00	Approx. $10.00

a/ Of material that is 3.5 percent active containing 70 million International units per gram. 1 quart contains 4 billion International units (Thuricide).
b/ Prices were announced at $2.55 for purchases by federal agencies, August 1978.
c/ The price on a current contract for 50,000 acre equivalents is $5.00 + per acre.
d/ Needs to be circulated each time prior to loading.
e/ Has to be used within 48 hours of mixing.
f/ Does not include administrative and environmental monitoring costs.

Table V-4

Assumptions - tussock moth

	Low estimate	High estimate
a. Annual growth rate/acre a/	.13 mbf	.20 mbf
b. Rotation length a/	60 yrs.	120 yrs.
c. Regulation period a/	40 yrs.	10 yrs
d. Average volume/acre a/	9.01 mbf	12 mfb
e. Reforestation cost a/	$120/acre	$300/acre
f. Natural regeneration a/	50%	
g. Timber sale price b/	$60/mbf	
h. Acreage infested c/	500,000	
i. Acreage sprayed c/	350,000	
j. Interest rate a/	10%	
k. Years of growth affected e/	3	
l. % of stand mature d/	78.6	
m. % of stand immature d/	21.4	
n. Salvage value f/	$44.80	
o. Percent timber salvageable e/	66.9	
p. Immature timber age e/	30 yrs.	
q. Operational effectiveness of control, e.g. incomplete spraying, natural mortality	90%	

a/ Estimate of study team and USFS timber management staff
b/ Estimate of past USFS sales
c/ Estimate by study team
d/ Timber statistics
e/ USFS-DDT Request 74
f/ USFS-DDT Request 74 adjusted to present price

Table V-5

Estimated losses and induced costs of an uncontrolled attack on 350,000 acres of Douglas fir forest

Losses and costs	Low	High	Midpoint
		(Million dollars)	
Timber	14.70	21.50	18.10
Fire	11.99	16.90	14.45
Planting	3.33	8.32	5.82
Total losses	30.02	46.72	38.37

a/ The assumption was made that no economic losses could be quantified for the remaining 150,000 acres, lightly infested. Developed from data in the Economic Appendix for tussock moth.

Table V-6

Estimated losses and induced costs prevented by control of a tussock moth infestation on 350,000 acres a/

Losses and costs	Low	High	Midpoint
	(million dollars)		
Timber b/	13.24	19.50	16.30
Fire:			
DFB c/	6.00	8.50	7.25
Carbaryl d/	9.60	13.50	11.55
Planting	3.00	7.49	5.24
Total Losses Prevented Using:			
DFB	22.24	35.34	28.79
Carbaryl	25.84	40.35	33.09
DFB			
Control Cost:	2.84	4.62	3.73
Net Benefit:	19.40	30.72	25.06
Carbaryl			
Control Cost:	2.77	2.77	2.77
Net Benefit:	23.07	37.58	30.32
Difference in Net Benefit, Carbaryl vs DFB	3.67	6.86	5.26

a/ From data in the Economic Appendix for tussock moth.
b/ Assumes 90% effectiveness in reducing losses.
c/ Assumed to reduce fire costs by 50 percent.
d/ Assumed to reduce fire costs by 80 percent.

Table V-7

Expected value of timber mortality and growth loss on an average acre of each damage class sprayed with DFB and for total acreage sprayed. a/

Defoliation severity class	Expected acreage sprayed	Percent of total sprayed acres	Midpoint estimated timber loss/acre	Expected reduction in timber loss due to DFB control total area
	(acres)	(percent)	(dollars)	(mil. dollars)
Dead	13,700	3.91	223.58	3.06
Class I	41,800	11.94	169.09	7.07
Class II	207,450	59.27	27.44	5.69
Class III	87,050	24.81	5.56	0.5
Total	350,000	100.0	46.60	16.32

a/ Developed from data in Economic Appendix for tussock moth. Assumes approximately two-thrids of this loss is on federal land, with the remainder on state and private land.

VI. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFLUBENZUON USE FOR MOSQUITOES

VI. PRELIMINARY BIOLOGICAL AND ECONOMIC ASSESSMENT OF DIFUBENZURON USE FOR MOSQUITO CONTROL

CURRENT USE ANALYSIS

Current Controls

Diflubenzuron (DFB) has a temporary permit for mosquito control on sites excluding crops, areas used for food, feed, hay pasture, potable water or water for livestock. Broader registrations exist for fenthion, chlorpyrifos, parathion, temophos, methoprene and diesel oil. Non-chemical methods include mosquito-eating fish, aquatic vegetation control, and elimination of breeding habitats.

Over 500 public agencies in the United States and Canada have operational mosquito control programs. While some mosquito control is attempted by individuals around homes and outdoor recreation facilities, most control efforts are by organized mosquito abatement districts (MAD). Often a combination of control methods are used in a MAD. For temporary control, larvicides are applied to water where mosquitoes are breeding. Some insecticides kill adults as well and have been used for several years as residual treatments or space sprays. Source reduction (permanent control) includes use of mosquito-eating fish, control of aquatic vegetation, and elimination or management of water used for breeding sites.

Need for Control

Mosquitoes transmit a number of human and animal diseases. Partly because of a long history of control in the United States, diseases such as malaria, yellow fever, dengue and several forms of encephalitis are vitually unknown. Mosquitoes carrying some of these are still

found in the U.S. and, when not effectively controlled, can cause epidemics. In 1975, 2200 cases of mosquito-carried encephalitis were confirmed, including at least 30 deaths. In addition to health factors, mosquito control is justified on the basis of discomfort caused by bites, reduced productivity of outdoor workers, and loss of enjoyment of outdoor recreation sites.

Livestock are equally affected by mosquitoes. Diseases such as anaplasmosis, Equine Infectious Anemia, EEE , WEE, and VEE are transmitted by mosquitoes. The last named, Venezuelan equine encephalitis, threatened to seriously disrupt the rodeo season in 1972, because transporting horses from or through states with the epidemic was forbidden. Stress caused by mosquito bites also leads to reductions in milk production among dairy and weight gain in beef cattle.

COMPARATIVE PERFORMANCE EVALUATION

Comparative Efficacy

Fenthion, chlorpyrifos, and parathion will control both larvae and adults except in areas of high organophorphorus resistance (mainly central California). Temophos is an effective larvicide except in central California where resistance is high. Methoprene, a larvicide, is not effective against Culex larvae. Only DFB is an effective larvicide for all areas.

Diesel oil is an effective larvicide but is not recommended for large-scale control for reasons discussed below.

Because of label restrictions, DFB can probably be used on only 5 percent of currently controlled sites. It is the only feasible alternative, however, in areas where mosquitoes are resistant to

other insecticides.

Comparative Costs

Per acre chemical costs range from $0.20 for parathion to $5.40 for diesel oil (see Table VI-1). Cost of DFB will be approximately $1.20 per acre. Most Mosquito Abatement Districts are able to choose the less costly alternatives, other factors being equal.

Control Problems

Diesel oil and non-chemical control methods are precluded from areas where wildlife habitats are important to society, such as salt-marsh bird refuges. Manipulation such as draining or vegetation control is often undesirable in such areas. Diesel oil sprayed on water surfaces also renders the site temporarily useless for other activities such as fishing or boating.

ECONOMIC IMPACT ANALYSIS

User Impacts

At the present, mosquito resistance to the registered pesticides is found almost exclusively in central California, a highly productive agricultural region. Diesel oil is not an acceptable control method in most breeding sites because of its phytotoxicity. Failure to register DFB would leave some MADs in California with no effective control for all mosquitoes.

Mosquito resistance is expected to increase. Estimates are that this will build enough over the next five to ten years to require substitution of a new chemical on 10 percent of the acres currently treated.

Market Impacts

Because of the nature of the mosquito control program, market impacts were not investigated.

Consumer/Social Impacts

Livestock producers could face a yield loss if mosquito control in the area was less effective. Users of outdoor recreation facilities, such as a riverside park or a rural campsite, would find these places less enjoyable and would probably stop using them. Without effective control of mosquitoes, public health expenditures could be expected to rise. Increased risk of the spread of equine diseases carried by mosquitoes could interfere with enjoyment of sports and other events which involve the movement of horses from one region to another.

Given the label restrictions, however, the likelihood of these impacts due to loss of DFB for mosquito control is very low. The only area identified as having resistance problems with other insecticides is central California, and DFB can be used on only a small number of sites. Except in the case of an epidemic of either human or equine diseases, all impacts are expected to be negligible.

Limitations

Lack of data on the actual amounts of each insecticide used annually prevented a comparative analysis.

TABLE VI-1

Major Chemical Alternatives for Mosquito Control, Application Rate, and Chemical Treatment Cost Per Acre

Chemical	Rate of application per treatment (lbs. a.i./acre)	Cost per unit a.i.		Chemical cost per treatment ($/ acre)
		dollars	unit	
parathion	0.100	2.00	lb.	0.20
chlorpyrophos	0.050	12.00	lb.	0.60
temophos	0.050	12.00	lb.	0.60
fenthion	0.100	7.00	lb.	0.70
methoprene	0.025	80.00	lb.	2.00
DFB	0.025	48.00	lb.	1.20
diesel oil	12 gal.	0.45	gal.	5.40

APPENDICIES

APPENDIX III-A

Summary of Field Tests Demonstrating the Efficacy of Diflubenzuron in Controlling Boll Weevil Populations a d Maintaining Beneficial Insect Populations

APPENDIX III-A

Summary of Field Tests Demonstrating the Efficacy of Diflubenzuron in Controlling Boll Weevil Populations and Maintaining Beneficial Insect Populations

Seasonal Development of Boll Weevil

Boll weevil development (i.e., population increase) requires food and favorable weather. Cotton squares are the preferred food for rapid development of the immature stages and for the high rates of egg-laying by the adults. The rate of development in bolls is somewhat slower and bolls become unsuitable for egg deposition at about 16 days of age.

A mean tempature in the low 80's is optimum for rapid weevil population increase. Interestingly enough, the mean July temperature throughout the U.S. boll weevil belt ranges from 78 to 86 F., optimum for the boll weevil.

The immature stages (egg, larva, pupa, and callow adult) are passed in 2 weeds in squares at optimum temperatures. The previposition period requires 5 or 6 days. This gives a minimum generation time of 2 1/2 to 3 weeks.

The egg-laying period lasts for 3 to 6 weeks-as long or longer than the developmental period. Some 250 to 300 eggs are laid by a female weevil.

Infested squares turn yellow, flare, and usually drop to the ground. Here they may be exposed to fatal high temperature, commonly referred to as "sum kill." The squares detached from the plant are subject to dissication, which may prove fatal to the larvae and papae. The combination of hot, dry weather is the most common mortality facotor limiting the rate of increase of boll weevil populations during summer when food is abundant.

Weevils starve in the absence of food except when they are in a state of repreductive diapause. Weevils in dispause survive from one crop year to the next.

Complete description of seasonal population development in fruiting cotton is complex. Diapausing boll weevils enter the following crop over a long time period, often a month after fruiting has begun. The egg-laying period is usually longer than the developmental period, giving a complete overlap of generations. Weather affects developmental rates, egg-laying period is usually longer than the developmental period, giving a complete overlap of generations. Weather affects developmental rates, egg-laying, and mortality. Weevils enter diapause, removing then from the reproducing population.

A practical alternative to complete analysis of this complex interplay of factors is simply to measure populations by field scouting. Boll weevil populations increase 2.5-fold weekly under favorable conditions. Hot, dry weather reduces this rate, often drastically. As the fruit load shifts from mostly squares to mostly bolls, the increase rate slows down.

A given field may provide abundant squares for weevil development for 6 to 9 weeks, depending on soil fertility, variety, weather, irrigation etc. At 2.5-fold rate of weekly increase, the seasonal population increase would be 100-fold in 6 weeks and 1,600-fold in 9 weeks.

A boll weevil control program, as presently practicided, utilizes the actual rate of increase in deciding whether or not to apply insecticides. In a boll weevil elimination program, it would be prudent to assume the maximum rate of increase.

The Development and Efficency of Diflubenzuron for Boll Weevil Suppression

Diflubenzuron has been tested for harmful effects on at least 10 species or groups of parasites and predacious arthropods that commonly occur in cotton fields. Laboratory and cage tests in Texas and Missouri have demonstrated that diflubenzuron has no lethal or sublethal effects on 3 species of parasites that attack eggs and larvae of the cabbage looper, lollworm, and the tobacco budworm. In Missouri, diflubenzuron applied at 5 times the recommended rate caused no significant mortality to immature and adult lady beetles, big-eyed bugs, and green lacewings. However, at higher dosages diflubenzuron did cause some mortality in green lacewing larvae, and in the Texas studies disrupted reproduction in that species.

Although laboratory studies in Texas and North Carolina showed diflubenzuron interfered with egg hatch in a species of a lady beetle, these predators soon recovered when exposure was terminated. In the North Carolina study, diflubenzuron did not harm big-eyed bugs.

Field studies were conducted to determine the impact of diflubenzuron on populations of beneficial arthropods in cotton fields in Texas and North Carolina. Texas studies indicated there were no significant differences between opoulations of beneficials in diflubenzuron treated and untreated fields. In North Carolina only populations of big-eyed bugs showed possible reduction as a result of the diflubenzuron treatment. In contrast, both North Carolina and Texas studies showed that the use of conventional insecticides drastically reduced beneficial arthropod

populations. Therefore, the harmful effects of diflubenzuron on beneficials insects appears to be small while offering selective control of the boll weevil. Conservation of beneficial insects can result in fewer outbreaks of lepidopteran pest species.

In 1977, Ganyard et al (unpublished) applied 8 applications of diflubenzuron to all cotton fields in Chowan County, North Carolina, at weekly internals between June 18 and August 4. Half of the fields received 0.03125 lb/acre while the other fields were treated with 0.0625 lb/acre. There was not a detectable difference in effectiveness between treatments. However, overwintered boll weevil populations were extremely low and evaluation was difficult.

In 1977, on the Rolling Plains of Texas, 3 applications of diflubenzuron were applied at the rate of 0.06 lb/acre during a 3-week period. Tidwell (unpublished) reported all eggs examined in infested squares failed to hatch.

The efficacy of diflubenzuron against the boll weevil has been clearly demonstrated by all researchers who have tested it at many locations across the boll weevil infested part of the cottonbelt. Field research with diflubenzuron against the boll weevil has been conducted in such a way so as (1) to initially determine efficacy and (2) subsequently determine dosage and interval. In initial tests, diflubenzuron was applied to cotton plantings at relaitvely high dosages and frequent (4- or 5-day) intervals. In the initial field tests in 1974 and 1975, 15 or 16 applications of diflubenzuron applied .25 and .5 lb ae per acre. Subsequently in 1976, fewer treatments

(3 to 12) applied at 5 to 7 day intervals with dosages of 0.0625 and 0.125 lb/acre were found to be highly effective in suppressing boll weevil populations. In addition, several tests were conducted in 1976 comparing the effectiveness of 0.03 and 0.06 lb/acre. In most experiments both dosages appeared equally effective. However, at one location (Florence, South Carolina) the 0.06 lb/acre dosage appeared superior to the 0.03 lb/acre rate.

In 1976 at Altus, Oklahoma, Coakley applied 6 applications of diflubenzuron at weekly intervals at 0.03, 0.06 and 0.12 lb/acre. All dosages effectively suppressed the boll weevil populations.

In Arkansas during 1976, Lincoln applied 6 or 7 applications of diflubenzuron at rates of 0.03, 0.06, and 0.12 lb/acre. All treatments effectively suppressed the boll weevil population.

In 1977, Ganyard et al applied 8 applications of diflubenzuron to all cotton fields in Chowan County, North Carolina, at weekly intervals at dosages of 0.03 and 0.06 lb/acre. There was no detectable difference between treatments. This experiment was conducted from the viewpoint of eradication. If the goal has been seasonal suppression of boll weevil population, fewer treatments would have been needed.

Present research findings and expert opinions across the cotton-belt indicate that 6 applications of diflubenzuron (0.0625 lb/acre) applied at weekly intervals will effectively suppress boll weevil populations so that other insecticidal measures will usually not be required to control the boll weevil.

Use of Beneficial Arthopods for Control of Heliothis

The importance of predators in regulating populations of Heliothis has recognized for many years (Quaintance and Brues, 1905; Fletcher and Thomas, 1943; Ewing and Ivy, 1943; Whitcomb and Bell, 1964; vanden Bosch and Ha en, 1966, Lingren et al, 1968).

There are probably 350 to 600 or more beneficial insects associated with cotton fields (Whitcomb and Bell, 1964; vanden Bosch and Hagen, 1966). However, Ridgway (1969) found in Texas that 10 to 15 species are probably the principal regulators of Heliothis populations. Some of the more important predators are the big-eyed bugs, Geocoris spp.; damsel bugs, Nabis spp.; flower bugs, Orius spp.; green lacewings , Chrysopa spp..; and lady beetles, Hippodamia spp.; and Colemegilla spp.

Ridgway et al (1969) established that approximately 200 to 2,500 bollworm larvae were required to cause economic damage to cotton during July and August under Texas conditions. Populations of Heliothis spp were suppressed by inundative releases of Chrysopa spp larvae gave effective bollworm/tobacco budworm control. Ridgway and Jones (1968) showed that releases of 292,000 Chrysopa larvae/acre reduced numbers of Heliothis larvae by 96% and resulted in yields 3-fold greater than the untreated control. Similarly, Ridgway and Jones (1969) found that releases of Chrysopa eggs at the rate of 50,000 and 200,000 per acre provided effective control of tobacco budworms. These authors concluded that the release of 50,000 Chrysopa eggs per acre gave adequate control of Heliothis populations.

Conservation of naturally occurring predators and parasites is of importance in regulating Heliothis populations. The selection and use of selective insecticides which do not destroy these natural enemies not only conserves naturally occurring beneficial insects but also makes augmentation by supplemental releases a feasible approach to Heliothis control.

Impact of Diflubenzuron on Beneficial Arthopods

Diflubenzuron has been treated for harmful effects on at least 10 species or groups of parasites and predacious arthropods that commonly occur in cotton fields. Laboratory and cage tests in Texas and Missouri have demonstrated that Dimilin has no lethal or sublethal effects on 3 species of parasites that attack eggs and larvae of the cabbage looper, bollworm, and the tobacco budworm. In Missouri, Dimilin applied at 5 times the recommended rate caused no significant mortality to immature and adult lady beetles, big-eyed bugs, and green lacewings. However, at higher dosages Dimilin did cause some mortality in green lacewing larvae, and in the Texas studies disrupted reproductions in that species.

Although laboratory studies in Texas and North Carolina showed Dimilin interfered with egg hatch in a species of a lady beetle, these predators soon recovered when exposure was terminated. In the North Carolina study, Dimilin did not harm big-eyed bugs.

Field studies were conducted to determine the impact of Dimilin on populations of beneficial arthropods in cotton fields in Texas and North Carolina. Texas studies indicated there were no significant differences between populations of beneficials in Dimilin-treated and untreated fields. In North Carolina only populations of big-eyed bugs showed possible reduction as a result of the Dimilin treatment. In contrast, both North Carolina and Texas studies showed that the use of conventional insecticides drastically reduced beneficial arthropod populations. Therefore, the harmful effects of Dimilin on beneficial insects appears to be small while offering selective control of the boll weevil. Conservation of beneficial insects can result in fewer outbreaks of lepidopteran pest species.

Qualitative Biological Assessment of Diflubenzuron

Diflubenzuron is a specific action insecticide which could be applied to prevent reproduction by the boll weevil without significantly interfering with natural control provided by parasites and predators of the bollworm - tobacco budworm complex. Presently used organophosphorus insecticides applied for boll weevil control limits use of bollworm control procedures to broad spectrum insecticides applied at high dosages. The use of diflubenzuron applied for boll weevil control will provide new opportunities for bollworm control: natural predators alone; natural predators + bollworm ovicides; natural predators + bollworm pathogens; and natural predators + released predators and/or parasites; and perhaps other methods not yet developed.

Currently used organophosphorus insecticides delay plant maturity and time of crop harvest. The use of diflubenzuron will result in earlier harvesting of the crop, potentially reducing losses due to unfavorable weather during harvest period, and perhaps increasing yields when the crop is extremely late.

If experimental pyrethroid insecticides are registered for use on cotton and are substituted for currently used organophosphate insecticides, the cost for controlling bollworms and tobacco budworms will increase substantially. The use of Dimilin in many parts of the cotton belt should substantially reduce the need for these more costly insecticides.

Within the past 15 years, the extensive use of certain weed control herbicides as well as organophosphate insecticides have delayed the maturity of the cotton crop. The effect of delayed maturity of the cotton crop, reduced cotton acreage, and increased corn acreage (as well as other changes) in some areas have substantially increased the need for controlling bollworms and tobacco budworms on cotton during late-season. High dosages of organophosphate insecticides applied for control of bollworms and tobacco budworms on

cotton during August and September effectively reduce boll weevil populations concurrently and result in lower boll weevil populations the next crop season.

Research at several locations has resulted in earlier fruiting cotton varieties which have been released for grower use. These earlier fruiting varieties have the potential of reducing the bollworm - tobacco budworm problem by setting and maturing an earlier crop thus escaping large late-season bollworm - tobacco budworm populations. Should the use of earlier fruiting varieties or other technical advancements result in reduced reliance upon high dosages of organophosphate insecticides for control of bollworm - tobacco budworm populations, then boll weevils would again be the major insect of cotton in these Areas. The potential use of diflubenzuron for boll weevil suppression would be highly advantageous.

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Diflubenzuron's Relationship to IPM

Insect control in cotton production has undergone a significant transition which bodes well for growers, consumers, and the environment. This transition is a bridge between two pest management regimes. The prevailing regime, emphasizes the authomatic-schedule spraying of insecticides. The second regime, which is becoming more widely accepted emphasizes the evaluation of pest management practices in light of the appropriate system dynamics; the generic name for this practicide is integrated pest management (IPM). Operationally, IPM users utilize pest scouting, phermone traps, the use of quick maturing varieties of cotton, the use of nontoxic chemical controls, the use of parasitic and predator controls, release of sterile male insects, the use of viruses and bacteria which will reduce pest population, new cropping and tillage techniques and the judicious use of toxicants.

Cotton growers have increasingly become aware of the long run and short tun advantages of switching to a multidimensional program to reduce pest damage with the results being both no reduction in profitability and reduction in the number of pounds and the number of kinds of toxicants which are discharged into the air, water, and land.

Citing from the National Ctton Council of American's rebuttal against the RPAR of toxaphene (date 10/12/77):

> In 1972 about 3,366,000 acres of cotton (approximately 25 percent of the crop) were scouted and under pest management[1/]. Approximately 25 percent of this was scouted by extension-trained growers, 25 percent by extension scouts, 40 percent by private consultants. In 1976 about 3,973,500 acres of cotton were scouted in this fashion[2/].

This represents about 37 percent of the harvested cotton. Excluding the 2,500,000 acres of cotton in the Texas High Plains where insects were not a major problem, the percentage jumps to about 47.

It has been demonstrated that the increased use of scouting and other IPM techniques can reduce the need for strict adherence to toxicant only management strategies. The Environmental Protection Agency contracted for a study of comparative efficacy of IPM verses conventional pest management regimes. Several crops were studied; there was large section on cotton which was geographically diverse and thorough in analysis. The following data is presented here for illustration purposes and not predictive of diflubenzuron's use efficacy in an IPM regime.

(1) For the year under, study cotton yields using IPM yields showed an increase in 11 of 13 programs; in two programs there were no yield changes. Yield increases ranged from 80 to 230 pounds of cotton per acre.

(2) Among IPM users 14 of 17 pest management programs which collected data founds that the use of insecticides fell by $3 to $4 per acre or a decrease of 20 to 86 percent meaning 2 to 4 pest control applications per year. Three of the programs noted increases in insecticide use.

(3) Of the 16 programs which adequate data was available, 15 noted an increase in farm profits.

(4) The above trends were coroborated by a statistical analysis of California data.

IPM is a viable alternative to conventional pest management strategies

How Can Diflubenzuron Be Utilized in a IPM Regime?

There are six stages of development for upland cotton. Each stage provides a distinct environment for pest activity and consequently a distinct pest management technique may be required if broad spectrum toxicants conflict with the goals of an IPM production process.

The six stages of development are planting stage, seedling stage, early season, mid season, late season, and fall season. The dominant pests are chronologically thrips, aphids, cutworms, plant bugs, flea hoppers, boll weevils, bollworm and tobacco budworm. Treating every pest with traditional toxicants can exacerbate subsequent pest problems (for beneficial insects which tend to reduce pest infestation are often killed along with the damaging pest).

Diflubenzuron is used to treat boll weevil infestation. Its most attractive characteristic, in terms of IPM features, is that beneficial insect populations are undisturbed and the need for other pest management techniques can be reduced.

The two major pests confronting most cotton producers are boll weevils and the boll worm tobacco bud worm complex. For example, it has been reported if thrips, plant bugs, and spider mites are not treated in Alabama the yield loss expected would be less than five percent, for Mississippi if the same insects went untreated less than a ten percent decline in yields is anticipated. However, if boll weevils and bollworm-budworm go untreated the crop will not be worth harvesting[1/].

1/ Cotton Insect and Weed Loss Analysis, Donald V DeBord, Dec. 1977, The Cotton Foundation.

Since diflubenzuron has not been field tested under conditions intended to simulate an IPM regime it is not possible to quantify diflubenzuron's contribution toward the successs of IPM. However, the availability of two non-toxic chemical Heliothis control treatments suggests a regime which may permit weevil/worm treatment while facilitating the action of beneficial predators and parasites. Chloridimeform and *Bacillus thuringensis* are both used for bollworm-budworm control.

Chloridimeform is an ovicide; this egg-killing ability is not found in many insecticides. The bacterium, *Bacillus thuringensis* is a seductive worm killer which acts by paralyzing the worms gut and the inflicts the worm with a highly specific disease; feeding soon halts and the worm dies within few days.

One can imagine a pest management program which includes the use of close scouting, diflubenzuron (for treating weevils), chlordimeform and/or *Bacillus thuringensis*, and the late season use of toxicant for reproductive-diapause boll weevil control. Application rates and schedules for application cannot be conjectured. Furthermore, yield changes and grower cost cannot be estimated. What can be qualitatively estimated is that diflubenzuron use contributes toward an IPM regime which may significantly reduce the load of organphosphates and chlorinated hydrocarbons which cotton production has discharged into the environment.

Lastly it should be noted that currently used ogranophosphorus insecticides delay plant maturity and time of crop harvest. The use of diflubenzuron will result in earlier harvesting of the crop, potentially reducing losses due to unfavorable weather during the harvest period, and perhaps increasing yields when the crop is extremely late. Also early maturing crops reduce losses due to Heliothis and contribute toward diapause control.

APPENDIX III-B

Example of Calculations in Table III-5

APPPENDIX III-B

Example of Calculations in Table III-5 Using FEDS Area 400 in Georga: Cost Savings from Substituting Diflubenzuron for Currently Used Insecticides to Control Boll Weevil and Bollworm-Budworm (Heliothis)

1.	"Acreage in Area" - total cotton acreage in FEDS region (1975).	75,700 acres
2.	"Control Costs with Currently Used Insecticides, All Insects" - area average of insect control costs, including insecticide material and application (1975 data inflated to 1977 price level).	\$92.24/acre
3.	Cost of controlling insects other than boll weevil and bollworm-budworm with current insecticides - proportion of weevil-infested acreage where concurrently occurring insects would render diflubenzuron ineffective, multiplied by line 2. (The proportion, 2.3 percent, came from the questionnaire results.) (.023)(\$92.24) = \$2.12	-\$2.12/acre
4.	Boll weevil and bollworm-budworm (Heliothis) control cost" using current insecticides - line 2 minus line 3.	= \$90.12/acre
5.	Boll weevil treatment cost using current insecticides - application cost (\$3.00) multiplied by number of applications (10). (Data from questionnaire results.) (\$3.00)(10) = \$30.00	-\$30.00/acre
6.	Bollworm-budworm (Heliothis) control cost using current insecticides - line 4 minus line 5.	= \$60.12/acre
7.	"Value of Natural Predators" of bollworm-budworm using diflubenzuron - percent reduction in acre treatments necessary to control bollworm-budworm when natural predators are not interfered with, multiplied by line 6. (The percent reduction, 30 percent, came from the questionnaire results.)(.3) (\$60.12) = \$18.04	-\$18.04/acre
8.	"Residual Bollworm-Budworm (Heliothis) Control Cost" - line 6 minus line 7	= \$42.08/acre
9.	Seasonal costs of controlling boll weevil with diflubenzuron - (\$3.00/oz. a.i. + \$0.40/2 qts. oil carrier + \$1.50/acre application cost)(6 applications per season)	+\$29.40/acre
10.	"Cost of Diflubenzuron Regime" - line 8 plus line 9	= \$71.48/acre
11.	"Savings from Use of Diflubenzuron Regime Per Acre" - line 4 minus line 10. (If zero or less, assume diflubenzuron will not be used, e.g. Alabama.)	\$18.64/acre
12.	Aggregate savings from using diflubenzuron regime - line 11 multiplied by line 1	\$1,411,000

HD

APPENDIX III-C

Annual Number of Applications to Control Boll Weevil, Currently Used Insecticides

Appendix III-C

Table 1

Annual Number of Applications to Control Boll Weevil, Currently Used Insecticides[a/]

Region and State	Number of applications by level of infestation[b/]		
	Low	Moderate	High
Southwest			
Alabama	3	6	12
Georgia	5	10	15
North Carolina	4	7	11
South Carolina	5	7	12
Delta			
Arkansas	0	5	10
Louisiana	3	5	12
Mississippi	3	5	12
Missouri	0	3	5
Tennessee	0	5	10
Southwest			
Oklahoma	1	3	6
Texas	5	8	12

a/ USDA/State/EPA Diflubenzuron Assessment Team for Cotton
b/ Numbers of applications for most efficient-least cost material.

APPENDIX III-D

Estimated Impact of a 5 Percent Yield Increase Resulting from Improved Cotton Pest Controls on 1.3 Million Acres

APPENDIX III-D

Table 1
Estimated impact of a 5 percent yield increase resulting from improved cotton pest controls on 1.3 mil. acreage

State and region	Acres	Average yield per acre in most feasible region	5% increase over average yield per acre	Total increase in production	Value of increase 2/
	1,000 acres	---------- pounds/acre	---------	1,000 lbs.	$1,000
Southeast					
AL	0.0				
GA	133.0	496.5	23.5	3,122.4	1,642.4
NC	56.0	390.0	19.5	1,092.0	574.4
SC	0.0				
Total	189.0	436.7	21.8	4,213.7	2,216.5
Delta					
LA	289.0	512.0	25.6	7,398.4	3,891.6
MS	712.5	443.0	22.2	15,781.9	8,301.3
Total	1,001.5	462.9	23.1	23,180.3	12,192.8
Southwest					
TX (total)	111.4	413.1	20.7	2,306.0	1,213.0
TOTAL	1,301.9	452.0	22.6	29,700.0	15,622.3

1/ Firm Enterprise Data System; weighted average of subregions included.

2/ Based on the pricr of cotton at $.526/pound. The price of cotton is a weighted average of prices received and quantity produced. USDA. 1977. Agricultural Statistics. USGPO, Washington, D.C.

APPENDIX III-E

Estimated Substitution and Displacement of Current Control Regime Insecticide Materials by a Diflubenzuron Regime for Suppression of Boll Weevil and Bollworm-Budworm on Feasible Acreage

Appendix III-E

Estimated Substitution and Dispalcement of Current Control Regime Insecticide Materials by a Diflubenzuron Regime for Suppression of Boll Weevil and Bollworm-Budworm on Most Feasible Acreage

The use of insecticides on cotton is of concern to growers in attempting to minimize the costs of production and to the public for health and environmental reasons. Diflubenzuron use based on existing data and expert opinion may serve as a substitute for existing boll weevil suppression materials. Also, because of the specific nature of diflubenzuron effecting only the boll weevil actions of the natural enemies of the bollowrm-budworm complex would delay the beginning of the control schedule, thus, displacing a few costly and intense insecticide treatments.

Appendix Table III-E

Table estimates the quantity of current, popualr materials substituted for and displaced by a diflubenauron regime. The distribution of materials is from the 1976 National Pesticide Survey, preliminary data USDA, and is considered homogeneous across the regions for purposes of analysis. The listed conventional insecticide materials are not exact substitutes in all cases (often user preference, atomospheric, and agronomic conditions dictate the choice of materials). The number of acre-treatments and the rates of application are from the USDA/State/EPA Diflubenzuron Assessment Team. The quantity of diflubenzuron used is calculated from the proposed total rate scheduling of 6 ounces per acre year.

An estimated total of 5,569.6 thousand pounds of boll weevil suppression materials would be substituted for 487.9 thousand pounds of diflubenzuron

on the feasible acreage and 8,264.9 thousand pounds of bollworm-budworm materials would be displaced by actions of the natural enemies. The average net decrease in insecticides applied per acre is 6.4 pounds.

Appendix table III-E

--Estimated substitution and displacement of current control regime insecticide materials by a diflubenzuron regime for suppression of boll weevils and bollworm/budworm on most feasible acreage. 1/

Quantity of current materials substituted for boll weevil suppression 2/

Region	Acres	Toxaphene	Methyl parathion	Azinphos-methyl	Other	Total
	Thous. acres	---- Thousand pounds active ingredients --------				
Southeast	189	430.7	870.1	107.7	35.9	1,444.4
Delta	1,001	1,501.5	1,501.5	375.4	125.1	3,503.6
Southwest	111	266.4	266.4	66.6	22.2	621.6
Total	1,301	2,198.6	2,638.0	549.7	183.2	5,569.6

Quantity of current materials displaced for bollworm/budworm control 2/

Region	Acres	Toxaphene	EPN	Methyl parathion	Mono crotophos	Other	Total
	Thous. acres	--------- Thousand pounds active ingredients ---------					
Southeast	189	484.6	72.7	315.0	24.2	72.7	969.2
Delta	1,001	3,224.0	483.6	2,095.6	161.2	483.6	6,448.0
Southwest	111	423.8	63.6	275.5	21.2	63.6	847.7
Total	1,301	4,132.4	619.9	2,586.1	206.6	619.9	8,264.9

Estimated total diflubenzaron use and the substitution or displacement of current materials

Region	Total estimated diflubenzuron use	Total substituted or displaced current materials	Net change in quantity
	Thousand pounds active ingredients		
Southeast	70.9	2,413.6	- 2,342.7
Delta	375.4	9,951.6	- 9,576.2
Southwest	41.6	1,469.3	- 1,427.7
Total	487.9	13,834.5	- 13,346.6

1/ Diflubenzuron substitutes for boll weevil suppression materials and displaces some bollworm/budworm controls by noninterference with natural enemies. Table III-5 for example of most feasible acreage. The price of diflubenzuron is assumed to be $3 per once.

2/ Major control materials were identified by the Federal/State Dimilin Assessment Team. They are assumed to be distributed homogenously throughout the United States. New insecticides such as synthetic pyrethroids are not included because of limited commercial use. The data are from USDA/ESCS, 1976 National Pesticide Use Survey.

APPENDIX IV-A

ESTIMATED SOYBEAN ACREAGE TREATED, BY STATE AND LEVEL OF INFESTATION: VELVETBEAN CATERPILLAR

APPENDIX IV-A, Table 1

Estimated Soybean Acreage Treated,
by State and Level of Infestation: Velvetbean Caterpillar[a/]

te	Velvetbean Caterpillar Alone[b/]				Velvetbean Caterpillar with Other Insects[c/]				All Velvetbean Caterpillar Acreage Treated			
	Low	Moderate	High	Total	Low	Moderate	High	Total	Low	Moderate	High	Tot[illegible]
	- - - - - - - -				1,000 acres			- - - - - - - -				
th Carolina	83	11	9	103	63	10	8	81	146	21	17	1[illegible]
rgia	300	101	56	457	178	64	36	278	478	165	92	73[illegible]
rida	32	119	65	216	11	39	21	71	[illegible]3	158	86	2[illegible]
bama-ssissippi	367	299	124	790	88	117	45	250	455	416	169	1,0[illegible]
isiana	149	44	23	216	127	38	19	184	276	82	42	40[illegible]
as	129	38	17	184	108	31	17	156	237	69	34	34[illegible]
ansas-Oklahoma	10	0	0	10	0	0	0	0	10	0	0	1[illegible]
TOTAL	1,070	612	294	1,976	575	299	146	1,020	1,645	911	440	2,[illegible]

Based on data from, USDA/State/EPA, "1978 Biological Survey for Diflubenzuron Use on Soybeans", unpublished.
Treated acreage on which velvetbean caterpillar is the only insect requiring control.
Treated acreage on which other insects require control concurrently with velvetbean caterpillar.

APPENDIX IV-B

WEIGHTED AVERAGE INCREASE IN SOYBEAN YIELD PER ACRE WITH DIFLUBENZURON COMPARED TO CURRENTLY USED INSECTICIDES FOR CONTROL OF VEVETBEAN CATERPILLAR, BY LEVEL OF INFESTATION

Appendix IV-B, Table 1

Weighted Average Increase in Soybean Yield per Acre with Diflubenzuron Compared to Currently Used Insecticides for Control of Velvetbean Caterpillar, by Level of Infestation

State	Level of Infestation			
	Moderate		High	
	Area Treated	Increase in yield	Area Treated	Increase in yield
	1,000 acres[a/]	bu./acre[b/]	1,000 acres[a/]	bu./acre[b/]
South Carolina	21	3.0	17	5.0
Georgia	165	1.5	92	3.1
Florida	158	.4	87	1.2
Alabama and Mississippi	416	.0	169	.4
Louisiana	82	.0	42	1.2
Texas	69	.0	34	1.2
Arkansas and Oklahoma	0	--	0	--
Weighted average	911	.41	441	1.44

a/ Appendix IV-A.
b/ Table IV-7.

APPENDIX IV-C

SUPPLEMENTARY DATA FROM THE
"1978 BIOLOGICAL SURVEY FOR
DIFLUBENZURON USE ON SOYBEANS"

APPENDIX IV-C, Table 1

Probability of Insect Infestation of Soybeans, by Insect and State[a]

Insect & State	Limited	Normal	Extensive	None
	-----	----- percent	-----	-----
Velvetbean Caterpillar				
South Carolina	20	60	20	--
Georgia	10	70	20	--
Florida	--	--	100	--
Alabama-Mississippi	60	30	10	--
Louisiana	10	80	10	--
Texas	10	70	20	--
Arkansas-Oklahoma	100	--	--	--
Mexican Bean Beetle				
Maryland-Virginia-Delaware	30	60	10	--
North Carolina	70	25	5	--
South Carolina	20	50	30	--
Georgia	90	9	1	--
Illinois-Indiana-Kentucky-Tennessee	100	--	--	--
Green Cloverworm				
Illinois	50	--	20	30
Ohio	90	--	10	--
Iowa-Indiana-Missouri	50	--	20	30
Kentucky	100	--	--	--
Arkansas-Oklahoma	100	--	--	--

a/ USDA/State/EPA, "1978 Biological Survey of Diflubenzuron Use on Soybeans," unpublished.

APPENDIX IV-C, Table 2

Proportion of Acreage Infested with Concurrent Insect Infestations, by Insect, State, and Extent of Infestation[a/]

nd	Limited		Normal		Extensive	
	Acreage with Concurrent Infestation[b/]	Probability of Occurrence[c/]	Acreage with Concurrent Infestation	Probability of Occurrence	Acreage with Concurrent Infestation	Probability of Occurrence
	percent					
an Caterpillar						
th Carolina	10	60	50	75	75	90
rgia	70	50	70	50	90	50
rida	--	--	--	--	30	83
bama-Mississippi	30	50	50	50	60	60
isiana	50	75	60	75	60	80
as	50	75	60	75	60	80
ansas-Oklahoma	5	10	--	--	--	--
Bean Beetle						
ryland-Virginia-Delaware	31	9	35	36	100	1
rth Carolina	--	--	5	50	5	75
uth Carolina	10	10	50	50	75	75
orgia	--	--	--	--	--	--
linois-Indiana-Kentucky-Tennessee	--	--	--	--	--	--
loverworm						
linois	2	10	2	10	2	10
io	--	--	--	--	--	--
wa-Indiana-Missouri	5	5	--	--	--	--
ntucky	--	--	--	--	--	--
kansas-Oklahoma	10	20	--	--	--	--

SDA/State/EPA, "1978 Biological Survey of Diflubenzuron Use on Soybeans," unpublished.
creage treated to control other insect pests concurrently with the target insect.
he probability of a year occurring with a concurrent infestation problem for each extent-of-infestation category.

APPENDIX IV-C, Table 3

Distribution of Acreage Infested with Velvetbean Caterpillar by Level of Infestation[a/]

State	Distribution of Acreage Infested								
	Limited			Normal			Extensive		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
	percent								
South Carolina	90	10	—	80	10	10	75	15	10
Georgia	100	--	—	70	20	10	50	30	20
Florida	—	--	—	--	--	--	15	55	30
Alabama-Mississippi	70	20	10	40	40	20	10	70	20
Louisiana	90	10	—	80	15	5	50	30	20
Texas	90	10	—	80	15	5	50	30	20
Arkansas-Oklahoma	100	--	—	—	--	--	—	--	—

a/ USDA/State/EPA, "1978 Biological Survey of Diflubenzuron Use on Soybeans," unpublished.

APPENDIX V-A

Economic Appendix

for Tussock Moth

ECONOMIC APPENDIX

The U.S. Forest Service analyzed the biological and economic impact of the uncontrolled tussock moth outbreak of 1972-73. This analysis was done in conjunction with the request that DDT be made available for use in 1974. This diflubenzuon (DFB) analysis draws heavily upon that information.

Impact of Timber Loss

The impact of the Douglas-fir tussock moth on the timber resource has been evaluated by examining the impact of a hypothetical outbreak. This section discusses the methods used in the analysis. All acres are commercial forest land.

The analysis used many of the same methods, assumptions and factors used in the USFS study and considered four impacts categories.

1. Mortality Loss- Mature Timber
2. Mortality Loss- Immature Timber
3. Growth Loss- Mature Timber
4. Growth Loss- Immature Timber

For purposes of this analysis, mature timber is defined as merchantable timber larger than 10 inches DBH (diameter breast height).

The calculations for each impact category involve essentially the same three steps: (1) the area involved, (2) the volume lost, and (3) the present value of the loss.

These loss estimates can be considered conservative. There is a possibility that a bark beetle outbreak may develop in trees weakened by the Douglas-fir tussock moth. This has not been taken

into account because no historical data exists to support a definitive calculation. Wickman (1958) reported that bark beetles kelled 75 percent of the total trees that eventually were lost in a 1956 tussock moth outbreak in California.

The damage class definitions used in this appraisal are as follows:

Damage Class

Dead	Areas on which most of the host type is dead as a result of prior years' defoliation.
I	Fifty percent or more of the host type has been completely defoliated.
II	Fifty percent or more of the host type has at least the top quarter of the crown completely defoliated.
III	Host type has defoliation visible from survey aircraft. The current year's foliage has been removed on most trees but less than a quarter of the crown has been completely defoliated.

Various assumptions were made concerning the timber susceptable to infestation by the Douglas-fir tussock moth. These assumptions concerned the volume/age, age classes, rotation length, growth rate/acre, sale value, salvage assumptions, and regulation period. All assumptions and their sources are listed in Table 1. Because of varying biological and management conditions under which Douglas fir is grown, a range of values was given for a number of the assumptions:

growth rate, rotation length, regulation period, volume per acre.

Estimated Timber Loss

The analysis of the hypothetical outbreak is an estimation of the volume and value impact to timber in the outbreak area as a result of defoliation by tussock moth larvae. The analysis of hypothetical damage is based on the areas of observed defoliation detected during an aerial survey conducted in the fall of 1973.

From the 1973 outbreak, acreage statistics by defoliation severity classes is known. The assumption of the study team was that 500,000 acres of the inland Douglas fir range would be affected during the nine year period. Of the 500.000 acres affected, between 300,000 and 400,000 acres would be treated. For the analysis it was assumed that 350,00 acres would be sprayed. It was also assumed that such spraying would take place on the most severly affected acreages and that the portion of the 500,00 acres which was not sprayed would suffer class III defoliation. On Table 2 the breakdown of the 350,000 sprayed acres is shown.

Mortality and growth are affected by the severity of defoliation. Mature and immature trees are affected differently. During the fall of 1973 aerial survey, it was estimated that 75 percent of the mature trees in Class I areas and 10 percent of the mature trees in Class II areas were dead. The Class III areas contained so few dead trees that no attempt has been made to account for the limited mortality in that damage class.

Calculation of Mortality Loss On Mature Timber

From Table 2 (expected sprayed area) and Table 3 (loss by severity class) Table 4 (a) was formed. This table gives the sprayed acreages for each severity class which would be expected to experience mortality if spraying did not take place. Table 4 (a) will also be referred to when calculating the growth loss on live acres.

The total acres of mortality (51,714) was multiplied by the average expected volume/acre and then by the expected stumpage value. This was done to arrive at the value of the mortality. Two expected volume/acre estimates were used (M 1 and M 2). These two estimates were expected by the study team to cover the range of values which would be encountered.

Of the mortality a portion would be salvageable. The salvaged timber would then be logged and sold even though dead and must be subtracted from the value of the mortality to arrive at the net loss. The figure for percent salvageable is a combination of the reduced value of salvageable timber and the portion of timber which it would be possible to remove and comes from combination of the area conditons observed in the USFS study. 1/ The percent salvageable timber is based on prior salvage experience, the need and feasibility of building roads to the affected stands, and other social and economic barriers to the recovery of the timber.

1/ The percent of value salvageable (Table 4b) is a combination of assumption e and assumption m (Table 1). Salvage value is a % of normal sale price times % of timber salvageable.

The mortality losses in mature timber were not discounted due to the near-term nature of the losses. The net figure at the end of Table 4 (b) is the net loss expected as a result of the infestation on acres of mature timber as a result of tree mortality.

Growth Loss Mature Timber

In addition to mortality the mature timber stands would also experience a growth loss. In Table 4 (a) the number of live acres was calculated as the remainder of the mature infested acres to be sprayed which did not experience mortality. The number of acres in total is 223,386. 2/

Research by Wickman (1963) has shown that a tussock moth infestation in white fir stands in California caused a reduction in annual growth on the surviving trees by a factor of .74 on Class I areas, .67 on Class II areas, and .31 on Class III areas. According to Wickman the trees require 3-5 years to return to their preinfestation annual growth rate. It has been assumed that the growth during the infestation plus the recovery time would be well represented by considering the growth reduction factor to be operable for three years. Although this work was done in California, it is the best information available for calculating growth loss due to tussock moth outbreak.

The acreage in each deoliation severity class was then multiplied by the percent growth loss stated in the above paragraph and also

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2/ These acres are not geographical acres they are a convience for calculation. They represent the total area, portions of which may be found scattered throughout the infected stands.

by the average annual growth rate and the number of years affected to arrive at the growth loss. Two estimates of average annual growth rate were used (M 1, M 2). These growth rates were expected by the study team to cover the conditions encountered on both managed and unmanaged stands. The conservative figure of three years of growth loss was used.

The two estimates of growth loss were then multiplied by the stumpage value to arrive at the stumpage value of the growth loss.

The actual value of the growth loss (present new worth, PNW) is dependent upon the regulation period (the number of years which will lapse before the stand is returned to for cuttings). If a stand is to be cut in the near future the PNW of the growth loss is higher than for a mature stand which would be cut at a later date. 3/ A discount factor is thus necessary to account for the regulation period. For a regulation period of n years and an interest rate of i the discount factor is determined from the following formula.

$$\text{discount factor} = \frac{1}{n} \times \frac{(1 + i)^n - 1}{i\,(1 + i)^n}$$

In the calculation an interest rate of ten percent was used and two estimates of cutting cycles (10 years, 40 years) were used. The estimates of the cutting cycles are expected to cover the range of management practices to be encountered on both government and private lands.

The two estimates of stumpage value of growth loss were then multiplied by the two discount factors formed by the two estimates

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3/ This refers to mature timber which is being held until the cutting cycle reached the land area on which it is grown.

of the regulation period (Table 4 c). Four numbers result; only two of these numbers, the high and the low estimates will be seen quoted in later tables. The middle estimates are retained in the table should the reader care to estimate a more concise final estimate from their own combination of the assumptions.

Immature Timber

In addition to the loss on mature timber a loss of both mortality and growth will be experienced by the infested immature portions of the timber stands. The acres of immature stands were calculated on Table 2 for each defoliation severity class. Table 5 (a) was calculated in a manner similar to Table 4 (a) except it is for immature rather than mature timber. The acreage (from Table 2) and the mortality (Table 3) both change for immature stands. As with mature timber, the live acres are the acres remaining after the infested acreages in each severity class have been multiplied by the mortality to arrive at the dead acres.

For immature stands the present net worth of any loss is dependent upon the rotation period (the length of time a tree is allowed to grow before being cut). The sale value of the mortality or growth loss must be discounted from the time the timber sale would actually take place back to its present worth.

The present net worth (PNW) of the loss resulting from the mortality of immature stands was assumed to be well represented by subtracting the PNW of a stand at rotation age from the PNW of the same stand at rotation age less 30 years. The value of a \$1 payment discounted for n years is calculated as follows:

$$\frac{1}{(1 + i)^n}$$

This multiplier is used to find the present value (V_o) of a future payment or value in n years (V_n), which may be a cost or an income, discounted annually for n years at the interest rate i. To find the present value, multiply the future value by the multiplier for the desired rate i and years n:

$$V_o = V_n \frac{1}{(1 + i)^n}$$

The multiplier was calculated for the rotation age (K) and for K-30 years.

$$N = \frac{1}{(1 + i)^{(K-30)}}$$

Where:

N = Discount factor C, the present value of $1 received at rotation age less 30 years

K = rotation age

i = interest rate, a discount rate of 10 percent was used as outlined in OMB Circular No. A-94 dated March 27, 1972

As with many of the other estimates encountered, a range of rotation ages was used. The range of estimates was 60 years and 120 years. It would be very difficult to find an estimate of rotation age for Douglas fir (or for true fir) which did not fall within this range.

The N discount factor at 10 percent for a 60 year rotation is .00573. For a 120 year rotation it is .00019.

Immature Timber Mortality Loss

The summation of immature dead acres (from Table 5 (a) was multiplied by the same range of two estimates of volume/acre that

were used for mature timber and then by the stumpage value to arrive at the value of the stumpage lost (Table 5 (b)). The stumpage value estimate in this case might be considered conservative for it assumes that in the future the constant dollar value of timber will be the same as today. Unlike mature timber, immature dead stands are not considered to be salvageable. The value of the lost stumpage at the time it would have been cut was determined to be from $10.7 to $14.3 million. Immature timber is assumed to be 30 years old.

This value must then be discounted back to the present day to arrive at its present net worth. As was shown in the previous section, the discounting depends upon the length of rotation. Both estimated rotations (60 years, 120 years) were used to arrive at the final high and low estimates.

Immature Timber Growth Loss

The live acres for each defoliation severity class (table 5) were multiplied by the growth reduction factor for that damage class to arrive at the growth reduction. The growth reduction factors are the same Wickman factor from the 1974 Tussock Moth Study which were used for mature timber. This growth reduction was then multiplied by the number of years the growth reduction was expected to take place (Table 5 (c)). Three to five years are estimated, three was chosen as in the 1974 USFS study. The total growth reduction was then multiplied by the growth rate to determine volume of loss. Two estimates of the annual growth rate were used (.13 MBF/year and .20 MBF/year) and were expected to cover the range of conditions which might be encountered. This volume of growth loss was then multiplied by its stumpage value to arrive at the harvest value of the loss. As

stated in the previous immature mortality section, is a conservative estimate. As was explained in the previous section covering immature timber it is necessary to discount these high and low estimates to the present day. Similarly to the immature mortality section, two estimates of the rotation period were used to arrive at the discount rates.

Calculation of Average Estimated Timber Loss/Acre

From Table 4 (a) and Table 5 (a) the percentages of dead and live acres in each defoliation class were entered on Table 11(a) (example: on Table 4 (a); 10,768 is 20.82 % of 51,714).

From Tables 4 (a) and 4 (c),and 5 (b) and 5 (c) the net loss in total on each age acre grouping and loss category is known. This number was multiplied by the percentages of Table 11 (a) to arrive at the dollar loss for each defoliation class (example: on Table 4(b) the low estimate for net loss is $14,201,900. This number multiplied by 20.82% is $2,956.8) Table 11 (c) is the last portion of Table 2, repeated for convenience.

Tables 11 (d) (1) and 11 (d) (2) are calculated in a similar manner; Table 11 (d) (1) for mature acres 11 (d) (2) for immature acres. The numbers are arrived at by dividing the Table 11(b) numbers by the Table 11(c) numbers in the respective categories. (Example : 2,913,100 divided by 10,768 is 270.53).

In Table 11(e), a total per-acre value for mortality and growth was estimated. This was done by taking the data in Table 11(d) (1) and 11(d) (2) times the percentage mature and immature in Table 11(e). For example, for mature timber, Class I, low estimate: 203.73

(Table 11(d) (1))times 78.6 percent = $160.13.

The numbers for mature and immature stands are totaled on Table 11(e) for each category. These numbers are reduced by 10% to account for operational. effectiveness. Table 11(f) is an average of the high and low catergories found on Table 11(e).

Table I . Assumptions - tussock moth

	Low estimate	High estimate
a. Annual growth rate/acre a/	.13 mbf	.20 mbf
b. Rotation length a/	60 yrs.	120 yrs.
c. Regulation period a/	40 yrs.	10 yrs
d. Average volume/acre a/	9.01 mbf	12 mfb
e. Reforestation cost a/	$120/acre	$300/acre
f. Natural regeneration a/	50%	
g. Timber sale price b/	$60/mbf	
h. Acreage infested c/	500,000	
i. Acreage sprayed c/	350,000	
j. Interest rate a/	10%	
k. Years of growth affected e/	3	
l. % of stand mature d/	78.6	
m. % of stand immature d/	21.4	
n. Salvage value f/	$44.80	
o. Percent timber salvageable e/	66.9	
p. Immature timber age e/	30 yrs.	
q. Operational effectiveness of control, e.g. incomplete spraying, natural mortality	90%	

a/ Estimate of study team and USFS timber management staff
b/ Estimate of past USFS sales
c/ Estimate by study team
d/ Timber statistics
e/ USFS-DDT Request 74
f/ USFS-DDT Request 74 adjusted to present price

Table 2-- Tussock moth-expected outbreak acreage by severity class and stand age

Defoliation severity class	Outbreak area 1973		Expected nine year outbreak			
			Infested area	Sprayed area		
				Total	Mature	Immature
(class)	(acres)	(%)	(acres)		(acres)	
Dead	17,270	2.74	13,700	13,700	10,768	2,932
Class I	52,620	8.36	41,800	41,800	32,854	8,946
Class II	261,190	41.49	207,450	207,450	163,056	44,394
Class III	298,420	47.41	237,050	87,050	68,422	18,628
Total	629,500	100.00	500,000	350,000	275,100	74,900

Table 3— Tussock moth - mortality and growth loss by severity class

Defoliation severity class	Mortality loss		Growth loss to surviving timber	
	Mature	Immature	Mature	Immature
(class)	(percent)		(percent)	
Dead acres	100	100	0	0
Class I	75	90	74	74
Class II	10	20	67	67
Class III	0	0	31	31

Table 4 -- Mature acres expected to be damaged by tussock moth

a. Acreage dead and live by severity class

Defoliation severity class	Acres sprayed	Mortality loss	Dead acres	Live acres
(class)	(acres)	(percent)	(acres)	(acres)
Dead acres	10,768	100	10,768	0
Class I	32,854	75	24,640	8,214
Class II	163,056	10	16,306	146,750
Class III	68,422	0	0	68,422
Total	275,100		51,714	223,386

b. Mortality loss							
	Acres	Average volume/acre	Stumpage value	Value of mortality	Percent of value salvagable	Value of salvage	Net loss 1/
	(acres)	(M.B.F.)	($/M.B.F.)	(dollars)	(percent)	(dollars)	(dollars)
M_1	51,714	9.01	60	27,956,588	49.2	13,964,876	13,991,712
M_2	51,714	12.00	60	37,234,080	49.2	18,599,167	18,634,912

1/ In the summary table these numbers are reduced by 10% to account for the assumed 90% operational effectiveness of control, e.g. incomplete spraying, natural mortality.

Table 4-c

c. Growth loss												
Severity class	Area	Average annual growth rate		Percent growth loss	Years affected	Growth loss		Stumpage value	Stumpage value of growth loss		Regulation period 1/	
	(acres)	(M.B.F./yr)		(percent)	(years)	(M.B.F.)		(dollars)	(dollars)		10 yrs. (.6144)	40 yrs. (.2445)
		M_1	M_2			M_1	M_2					
Class I	8,214	.13	.20	74	3	2,371	3,647	60	M_1	2,939,340	1,805,930	718,659
Class II	146,750	.13	.20	67	3	38,346	58,994	60	M_2	4,522,020	2,778,329	1,105,634
Class III	68,422	.13	.20	31	3	8,272	12,726	60				

1/ In the summary table these numbers are reduced by 10% to account for operational effectiveness.

Table 5(a) Immature acres expected to be damaged by Tussock Moth

Acreage of dead and live acres by severity class				
Severity class	Acres attack	Mortality loss	Dead acres	Live acres
(class)	(acres)	(percent)	(acres)	(acres)
Dead acres	2,932	100	2,932	0
Class I	8,946	90	8,051	895
Class II	44,394	20	8,879	35,515
Class III	18,628		0	– 18,628
Total	74,900		19,862	55,038

Table 5 (b)

Mortality loss						
Acre	Average volume/acre	Stumpage value	Value of stumpage	Value of mortality	Discount for rotation minus 30 years	
(acres)	(M.B.F.)	($/M.B.F.)	(dollars)	(dollars)	90 yrs. (.00019)	30 yrs. (.00573)
M_1 19,682	9.01	60	10,737,397	10,737,397	2,040	61,525
M_2 19,682	12.00	60	14,300,640	14,300,640	2,717	81,943

Table 5 (c)

Growth loss - immature timber						
Area		Growth reduction			Years affected	
(acres)		(percent)		(acres)	(years)	(growth area)
Class I	895	74	=	662		
Class II	35,515	67	=	23,795		
Class III	18,628	31	=	5,776		
	55,038			30,233	3 =	90,699

Annual growth rate		3 year volume of growth loss
(MBF/yr)		(MBF)
90,699 x M_1 .13	=	11,791
90,699 x M_2 .20	=	18,791

	Volume of growth loss	Stumpage value	Harvest value
	(MBF)	(dollars)	(dollars)
M_1	11,791	60	707,460
M_2	18,140	60	1,088,400

	Harvest value	Rotation period 1/	
	(dollars)	60 years (.00573)	120 years (.00019)
M_1	707,460	$6,237	$207
M_2	1,088,400	$4,054	$134

Table 6 (a) Summation of total timber damages

Age damage class	Low estimate	High estimate
	(dollars)	
Mature acres		
Mortality	13,991,712	18,634,912
Growth	718,669	2,778,329
Immature acres		
Mortality	2,040	81,943
Growth	134	6,237
Total	14,712,555	21,501,421

Table 6 (b) Summation of total damaged reduced by 10% to account for operational efficency

Age damage class	Low estimate	High estimate
	(dollars)	
Mature acres		
Mortality	12,592,540	16,771,420
Growth	646,802	2,500,496
Immature acres		
Mortality	1,836	73,749
Growth	121	5,613
	13,241,299	19,351,278

Table 7. Estimated timber loss prevented on USFS and State-private lands

Ownership	Midpoint estimate
Total	16,296,288
USFA (65%)	10,592,587
State-private (35%)	5,703,701

Table 8

Estimated losses and induced costs of an uncontrolled attack on 350,000 acres of Douglas fir forest

Losses and costs	Low	High	Midpoint
	(Million dollars)		
Timber	14.70	21.50	18.10
Fire	11.99	16.90	14.45
Planting	3.33	8.32	5.82
Total losses	30.02	46.72	38.37

a/ The assumption was made that no economic losses could be quantified for the remaining 150,000 acres, lightly infested. Developed from data in the Economic Appendix for tussock moth.

Table 9-- Estimated losses and induced costs prevented by control of a tussock moth infestation on 350,000 acres a/

Losses and costs	Low	High	Midpoint
		(million dollars)	
Timber b/	13.24	19.50	16.30
Fire:			
DFB c/	6.00	8.50	7.25
Carbaryl d/	9.60	13.50	11.55
Planting	3.00	7.49	5.24
Total Losses Prevented Using:			
DFB	22.24	35.34	28.79
Carbaryl	25.84	40.35	33.09
DFB			
Control Cost:	2.84	4.62	3.73
Net Benefit:	19.40	30.72	25.06
Carbaryl			
Control Cost:	2.77	2.77	2.77
Net Benefit:	23.07	37.58	30.32
Difference in Net Benefit, Carbaryl vs DFB	3.67	6.86	5.26

a/ From data in the Economic Appendix for tussock moth.
b/ Assumes 90% effectiveness in reducing losses.
c/ Assumed to reduce fire costs by 50 percent.
d/ Assumed to reduce fire costs by 80 percent.

Table 10 -- Acres of Douglas and fir-spruce types in the North and South Rocky Mts. (thousand acres)

Ownership age	Timber type: douglas fir	Timber type: fir-spruce	Total of both types	(% of total)
National forest				
sawtimber	5,332	5,743		
poletimber	911	854		
seedlings	636	751		
total	6,880	7,349	14,229	(65.6)
Other Public				
sawtimber	1,306	733		
poletimber	240	39		
seedlings	94	67		
total	1,641	840	2,481	(11.4)
total public	8,521	8,189	16,710	(77.0)
Forest industrys				
sawtimber	491	322		
pole timber	55	13		
seedlings	32	54		
total	579	390		
Farm and misc.				
sawtimber	2,112	322		
pole timber	517	13		
seedlings	154	54		
total	2,785	390		
total private				
Grand total				
sawtimber	9,243	7,799	17,042	(78.6)
pole timber	1,725	1,022	2,747	(12.7)
seedlines	916	978	1,894	(08.7)
total	11,884	9,800	21,684	

Table 11 (a) Claculation of the per acre losses-Douglas fir Tussock moth diflubenzuron control

	Percent of acres by damage class in each total			
	Mature		Immature	
	Mortality	Growth	Mortality	Growth
	(percent)			
Dead	20.82		14.77	
Class I	47.65	3.68	40.53	1.63
Class II	31.53	65.69	44.70	64.53
Class III		30.63		33.84
Total	100.00	100.00	100.00	100.00

Table 11 (b) Loss value of acres by damage class in each total

	Mature				Immature			
	Mortality		Growth		Mortality		Growth	
	High	Low	High	Low	High	Low	High	Low
	($1,000 dollars)							
Total	18,634.9	13,991.7	2,778.3	718.7	81.9	2.0	6.24	.13
Dead	3,879.8	2,913.1			12.1	.30		
Class I	8,879.5	6,667.0	102.2	26.4	33.20	.81	.10	.002
Class II	5,875.5	4,411.5	1,825.1	472.1	36.6	.89	4.03	.084
Class III			851	220.2			2.11	.044

Table 11 (c)

	Acres in each damage class	
	Mature	Immature
	(acres)	
Dead	10,768	2,932
Class I	32,854	8,946
Class II	163,056	44,394
Class III	68,422	18,628

Table 11 (d)(1) Expected timber loss/acre by damage class by mortality level (mature acres)

	Mature acres					
	Mortality		Growth		Total	
	High	Low	High	Low	High	Low
	(dollars)					
Dead	360.31	270.53			360.31	270.53
Class I	270.27	202.93	3.11	0.80	273.37	203.73
Class II	36.03	27.06	11.19	2.90	47.22	29.96
Class III			12.44	3.22	12.44	3.22

Table 11 (d) (2) Expected timber loss/acre by damage class by maturity level (immature acres)

	Immature acres					
	Mortality		Growth		Total	
	High	Low	High	Low	High	Low
Dead	4.12	.14			4.12	.14
Class I	3.71	.12	.01	< .01	3.71	.12
Class II	.82	.03	.09	< .01	.91	.03
Class III			.11	< .01	.11	.01

'able 11 (e) Expected loss reduced to growth mixture of average ace

	Value divided by % of acreage in total				Values of table II E(1) reduced by 10%			
	Mature (78.6%)		Immature (23.2%)		Mature		Immature	
	High	low	High	Low	High	Low	High	Low
'ead	283.20	212.64	.96	.03	254.88	191.38	.86	.03
'lass I	214.87	160.13	.74	.03	193.38	144.12	.67	.03
lass II	37.11	23.55	.21	.01	33.40	21.20	.19	.01
lass III	9.80	2.53	.03	.01	8.82	2.28	.03	.01

Table 11 (f) Average estimated timber loss/acre

	Mature	Immature	Total
		(dollars)	
Dead	223.13	.45	223.58
Class I	168.75	.35	169.09
Class II	27.30	.10	27.44
Class III	5.55	.01	5.56

[illegible]

APPENDIX VI-A

An assessment of the Need and Requirements for Mosquito Larvicides

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NEED AND REQUIREMENT FOR MOSQUITO LARVICIDES

Of arthropods and insects that attack and affect people, mosquitoes represent the most serious problem and threat to human health, comfort, safety, productivity and enjoyment of outdoor recreation (Anom. 1976). In addition they cause losses in production in the livestock industry.

World-wide, mosquitoes transmit a variety of human and animal diseases, the most important of which are malaria, yellow fever, various strains of dengue and dengue-haemorraghic fever, and a large variety of types of encephalitis. A great deal of progress has been made in the control of mosquito-borne diseases world-wide through improved living conditions and standards, health services and organized mosquito control programs. However, much remains to be done. World-wide malaria is the most important vector-borne disease and it is estimated (WHO 1975) that 500 million people exist in areas with no measures of protection against disease. In Africa, it is estimated that over 95 million cases of malaria occur each year with high infant mortality. In the Americas deaths due to malaria were still about 2,000 in 1967-69. Estimates of costs of malaria control range from less than $1/person/year to higher figures. Because of problems of resistance to insecticides, apathy occurring when programs are highly successful, and inability of developing countries to pay increasing costs of control, resurgence of malaria has been phenomenal. Only 9,500 cases of malaria were reported in Pakistan in 1968; but in 1975 there were 10,000,000 reported cases (Anon. 1975). Similar problems

of resurgence have been reported in Sri-Lanka and India.

In the continental U. S., the problem of malaria and yellow fever transmission has been eliminated through improved living standards, organized mosquito control programs and health services. However, the many species of mosquitoes that vector these diseases are still present and there is a continual threat of reintroduction. Mosquito-borne encephalitis exists throughout the U. S. in a variety of types and strains. When conditions favor high densities of mosquitoes, epidemics can and do occur. In 1975 some 2,200 cases of mosquito-borne encephalitis were confirmed with 30 known deaths. In 1971 (Spears, J. F., 1971-2; Reeves, 1972) the United States conducted the largest spray operation against mosquitoes to stop VEE epidemic. Cost of the program including spraying and immunization was about 20 million dollars.

Although mosquito-borne diseases are still a potential threat in the U. S., the primary reason for mosquito control is the vicious biting habits of high numbers of mosquitoes that annoy people, reduce productivity and prevent enjoyment of recreational activity and resources. Mosquitoes breed in all types of natural and man-made water sources from the icy waters from snow-melt in the north to hot, temporary water accumulations in the south as well as from water pure enough to drink to the foul, polluted water of sewage systems. Although the occurrence and abundance of mosquitoes varies greatly with locality and time, they can be considered distributed throughout the country.

Mosquitoes are also a serious problem in the production of livestock (Steelman et al. 1972, 1975, 1976 and 1977). Economic damage thresholds from mosquito attack on cattle produced under

Louisiana conditions (representing recommended breed-types and conditions above the normal stress factors of heat and vegetative nutrition levels) were exceeded from April through September and resulted in a reduction of $6.50/head (6-year average for all breeds). These data reflect only direct losses in production by blood-feeding attack. Rarely large mosquito broods can result in death of animals or the expense of moving animals. Indirect losses can occur from transmission of diseases such as anaplasmosis, VEE, EEE, WEE and Equine Infectious Anemia.

Thus, there is little doubt about the need for mosquito control throughout the United States and the world. It is impossible to calculate the benefits of mosquito control since we are dealing with values of life, health, comfort and enjoyment of the environment. What medical costs would have been required for the unknown number of cases of diseases that could have occurred without mosquito and disease control? What is the value of a human life or the enjoyment of recreational areas? What is the value of communities, industries and tourism developed in areas where mosquitoes previously prevented development? What value can be placed on the existence of the Panama Canal since it couldn't be completed until the problem of mosquito-transmitted yellow fever was conquered?

This group recognized the impossibility of determining the total benefits occurring from mosquito control and apportioning uncalculable benefits to specific control technologies or control chemicals. Therefore they agreed that the need for and justification of mosquito control was accepted and they would attempt to analyze the need for additional chemical control agents

in light of existing control practices and techniques.

A recent survey published in summary by the (A)merican (M)osquito (C)ontrol (A)ssociation (1977) listed 533 agencies in the United States and Canada with operational mosquito control programs. Although this group recognized that substantial sums of money are spent by individuals for repellents or insecticides for protection around homes and recreational areas, these types of uses or purchases are not included and information is restricted to operations conducted by public agencies. The AMCA summary reports mosquito control expenditures of $69,059,403 and the treatment of 4,713,845 acres with mosquito larvicides and 30,488,988 acres with adulticides. These figures should be considered as only rough estimates since we cannot be sure of a 100% response to the survey or that estimates of acres treated are precisely accurate, e.g., larvicides are sometimes applied to ditches, pot holes, or other irregular areas, and it is difficult to convert to acres treated. These estimates should be considered as minimums with the possibility of actual values being much higher.

Description of Current Control Practices

Mosquito control as practiced by organized mosquito control districts and other public agencies has to a large degree attempted to combine available control techniques. Of particular importance has been source reduction (sometimes referred to as permanent control) and the use of insecticides (sometimes referred to as temporary control). Source reduction involves the elimination or management and manipulation, where possible, of the water in which mosquito eggs occur and larvae and pupae

develop. Considering the variety of sources of water in which mosquitoes breed, source reduction is not as simple as it appears and not the only method required for mosquito control. A wide variety of insecticides have been developed and used over the years as residual treatments or aerosols or space sprays against adults and as larvicides applied to breeding water of mosquitoes. These two methods account for the majority of mosquito control activities; however, the use of mosquito-eating fish and the control or removal of vegetation in certain types of water sources has been useful.

Mosquito larvicides are one extremely useful tool in mosquito control operations. Since larvicides may be required in all or all sources of water, a variety of compounds has been developed for use in different situations. Because of resistance and environmental concerns the number of effective available larvicides has been reduced.

We have attempted to estimate actual usage patterns of larvicides in the contiguous 48 states of the U. S. in terms of geographical areas and types of water treated. Since actual figures of this type are not available, these figures represent only judgmental estimates. However, they should be helpful in assessing potential needs for mosquito larvicides.

Table 1 lists 8 geographical areas of the U. S. and gives the best estimate available of the number of acres larvicided (AMCA 1977) in these areas and the probable types of water that are involved in larvicide applications. Of the total of 4,188,145 acres reported as receiving treatment about half is estimated to be involved in treating salt-water and half fresh.

It would be advisable to determine the larvicides used in each area and type of water. However, these data are not available. Table 2 lists 6 of the major insecticides currently in use including rates of application and estimated costs with similar information for Dimilin; there is equal efficacy for each of these except (1) the organophosphorus compounds (Dursban, Fenthion, Parathion, Abate) are not effective against resistant populations in Central California and (2) Altosid is not operationally feasible against Culex species in most habitats.

Problems of Insecticide Resistance

In California the situation with respect to mosquito larvicides is unique due to the serious extent of insecticide-resistance in field populations. In many parts of the San Joaquin Valley Culex tarsalis, the vector of western equine and St. Louis encephalitis, is resistant to all commercially-available, organophosphorus larvicides (Schaefer, C. H. 1972). Following periods of unusually heavy precipitation it is necessary to treat large areas in order to prevent the build-up of Culex tarsalis populations; at the present time no effective larvicides are available that would allow mosquito abatement districts to accomplish this task should severe flooding occur.

Mosquito-borne encephalitis is a recurring problem in California; the number of confirmed cases of Western equine (WEE) and St. Louis encephalitis (SLE) from 1945 and 1973 is shown in Table 3. The greatest epidemic was in 1952; following this outbreak there were 50 human fatalities and of the WEE cases, 20-25% were in children of less than one year of age and 79% of these developed sequelae, of which 50% developed permanent brain

damage (Finley, 1967). Most of the children having severe cases became permanent wards of the state. The cost of care for such persons is considerable (average cost per patient in California mental hospitals is $1,800/mo. as of 1/1/78, personal communication from Dr. J. T. Shelton, Director Porterville State Hospital, Porterville, Ca.).

Encephalitis cases in adults (usually SLE) results in a minimum of 2 weeks hospitalization and such persons are unable to work for 4 to 6 weeks. Symptoms include severe headache, high fever, loss of reflexes, ultra-sensitivity to light and in severe cases persons enter into coma. There is no specific treatment except the use of antibiotics to prevent initiation of pneumonia (personal communication from Dr. W. C. Reeves, School of Public Health, University of California, Berkeley, Ca.).

Another important problem in California is the irrigated pasture mosquito, <u>Aedes nigromaculis</u>; this species is a severe pest annually. In the San Joaquin Valley, this mosquito is also resistant to all organophosphorus larvicides and mosquito abatement districts are forced to control the resulting adult populations with propoxur (a carbamate). For example, in 1976, 11,000 lb (active ingredient) of propoxur were applied in California (1977 Yearbook, California Mosquito and Vector Control Association). Since the treatment rate for propoxur is 0.05 lb per acre, a total of 220,000 acres was treated for adults because larviciding was not feasible.

The organophosphorus-resistant populations of both <u>Culex tarsalis</u> and <u>Aedes nigromaculis</u> can be controlled with Dimilin (Schaefer et al. 1975). There is a cummulative total of ca.

400,000 acres that are treated in the resistant areas.

Attempts to induce resistance to Dimilin by treating successive generations of organophosphorus-resistant mosquitoes in the laboratory have failed thus far; this is true even though over 30 successive generations have been pressured with Dimilin (unpublished data, Dr. G. P. Georghiou, University of California, Riverside, Ca.).

Alternative Control Measures

Considerable research is underway to develop biological control agents for control including fish, bacteria, fungi, microsporidians, viruses, nematodes and sterilization and genetic methods. Further developmental research is needed on methods of production, storage, packaging and delivery to target areas as well as safety testing before these alternative methods can be considered as alternative and economical replacements for existing control techniques. Although there are several promising biological control agents or techniques, none are currently available commercially.

Permanent control by removal or management of sources of water has been used for many years in mosquito control. Its cost effectiveness will vary with the type of water and habitat involved. One economic study in California (Sarham 1976) indicated that source reduction would be cheaper than the use of chemicals in achieving a 1% reduction in mosquitoes per light-trap night. Source reduction must be evaluated further in terms of multiple-use patterns of the water itself and the habitats in which it occurs.

Conclusions

There is a definite need for several larvicides to be available for use in mosquito control operations. The four organophosphorus insecticides listed in Table 2 have limited or no usefulness in certain areas where resistance is a problem. It can be anticipated that problems with insecticide resistance will increase over time. Further restrictions on the use of oil in environmentally important areas will restrict or reduce the use of oils for larval control. New, effective and safe larvicides are needed for control operations. As pointed out earlier, areas of California already have resistance problems which preclude the use of currently-used organophosphorous larvicides. Such areas exist in other parts of the world, particularly cotton-growing areas where mosquitoes are exposed to continued application of these types of insecticides. Effective mosquito control requires the availability of more than one effective and usable larvicide.

Since there is no feasible method of calculating the benefits in health, sickness, life or enjoyment of the environment of mosquito control in general or one specific larvicide as a part of total mosquito control operations, this group estimated the potential need for an additional larvicide for mosquito control in terms of probable or potential use within the next 5 to 10 years. We estimate that problems of resistance to currently available materials along with economic considerations and user acceptance could require a shift to a new chemical larvicide approaching 10% of the existing treatments reported.

Such a shift could involve 200,000 to 400,000 treated acres or 5,000 to 10,000 lbs of a chemical applied at a rate of 0.025 lbs/acre. It is possible that usage outside of the continental U. S. and increasing efforts in mosquito control would result in doubling or quadrupling these estimates.

The main projected use of Dimilin appears to be limited areas where strains are resistant to organophosphorus compounds. In other areas, lower cost alternatives are available and it is not likely that Dimilin would displace these as long as their effectiveness remains.

Registration of Dimilin would not provide for use in over 95% of the habitats where mosquitoes breed because of the existing Label. This Label excludes application on crops or in areas used for food, feed, hay, pasture or for potable water, livestock watering or for crop protection. Thus, until a broader Label is approved, there will be very little commercial use.

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Table 1.--Estimate of number of acres and type of water where larvicides were used in 8 areas of the U. S.

Region	Total acreage larvicided	Probable acreage of different types of water larvicided		
		Salt-marsh	Fresh	
			Permanent	Temporary
N-Atlantic	462,269	369,815	23,113	69,341
Mid-Atlantic	1,111,960	1,000,764	22,239	88,957
S-Atlantic	592,169	562,561	5,922	23,686
N-Central	223,420	0	44,684	178,736
S-Central	467,083	140,125	163,479	163,479
W-Central	270,141	162,085	54,028	54,028
N-Pacific	133,476	0	106,781	26,695
S-Pacific	927,627	27,829	92,763	807,035
Totals	4,188,145	2,263,179	513,009	1,411,957
			1,924,966	

Table 2.--Major insecticides used as mosquito[a/] larvicides including average rate per acre per treatment, cost per unit A.I., cost per acre.

Material	Rate per acre per treatment (lbs/acre)	Cost per unit A.I. $/unit	unit	Cost per acre per treatment ($/A.I./treatment)
1. Dursban	0.05	12.00	lb	0.60
2. Fenthion (Baytex)	0.10	7.00	lb	0.70
3. Oil (diesel)	12 (gal)	0.45	gal	5.40
4. Parathion	0.10	2.00	lb	0.20
5. Abate	0.05	12.00	lb	.60
6. Altosid	0.025	80.00	lb	2.00
Proposed				
Dimilin	0.025	64.00	lb	1.60

[a/] Cost of application ca. $1.10/acre (note: in granular form additional $.40/acre).

Table 3.--Human, laboratory-confirmed cases of mosquito-borne encephalitis, California, 1945-1973.

Year	WEE[a/]	SLE[b/]
1945	26	28
1946	18	10
1947	32	6
1948	-	1
1949	10	21
1950	88	69
1951	22	33
1952	375	45
1953	14	22
1954	22	99
1955	6	3
1956	14	7
1957	3	23
1958	37	16
1959	2	40
1960	1	12
1961	2	8
1962	5	16
1963	3	12
1964	10	2
1965	9	1
1966	9	8
1967	7	8
1968	11	4
1969	-	5
1970	-	2
1971	3	2
1972	3	5
1973	-	5

a/ Western equine encephalitis.

b/ St. Louis encephalitis.

Attachment 1

Mosquito Larvicides

Fenthion (Baytex) - Except in areas of high organophosphorus-resistance (central California), this material can be used against both larvae and adults at 0.1 lb/acre. It is effective against a wide variety of mosquito species. This product presents a toxicity problem in that at rates required for mosquito control Baytex can be harmful to wildlife and fish.

Dursban - Except in areas of high organophosphorus resistance (central California), this material is effective against mosquito larvae and adults at 0.05-0.1 lb/acre. It has a high residual action in polluted water (sewage lagoons, septic tanks, ditches with high organic debris) and in cathc basis and gutters. It is moderately safe to wildlife but is highly toxic to aquatic, non-target organisms especially since registered rates are harmful to crustaceans.

Parathion - Except in areas of high organophosphorus-resistance (central California), this material is effective against mosquito larvae and adults at 0.1 lb/acre. It is highly toxic to mammals, wildlife and aquatic, nontarget organisms and therefore its application must be carefully controlled; its low cost and perhaps varied methods of application (drip bucket and hand equipment) are the primary reasons for its widespread use.

Abate - This material is effective against mosquito larvae, except in areas of high organophosphorus-resistance (central California) at 0.05 lb/acre. It is generally safe to mammals, fish and wildlife and relatively safe to aquatic, nontarget organisms. It is economically feasible to almost all MAD programs.

Altosid - This material is effective against floodwater species of mosquito larvae at 0.25 lb/acre but is not effective against Culex larvae. It is generally safe to mammals, fish, and wildlife although it has been shown to be harmful to several non-target taxa at registered rates of application. The selected habitat use results in a low volume production and a high unit cost.

Oils - These petroleum products (largely diesel oil) are effective larvicides at rates of 10-15 gal/acre. The high treatment volume results in high cost and in a high degree of ferrying from storage facilities to treatment areas; consequently, large areas cannot be larvicided efficiently. It is also used to kill vegetation in various mosquito breeding habitats to aid in elimination of breeding sites.